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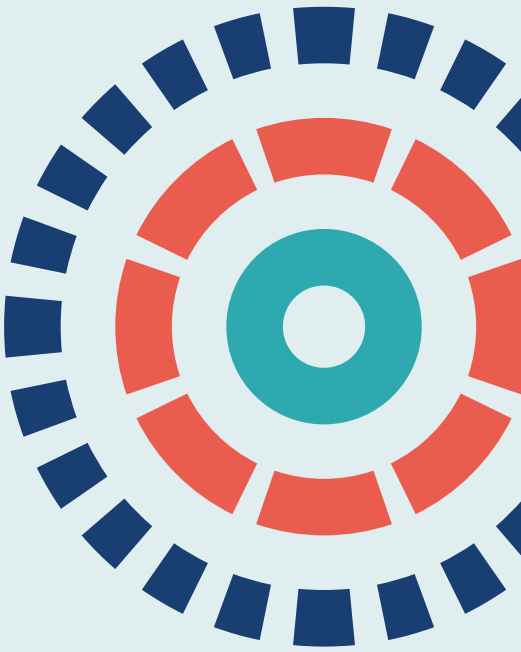

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Powered mobility interventions for very young children with mobility limitations to aid participation and positive development: the EMPoWER evidence synthesis

Nathan Bray,[1,2*] Niina Kolehmainen,[3,4] Jennifer McAnuff,[3] Louise Tanner,[3] Lorna Tuersley,[2] Fiona Beyer,[3] Aimee Grayston,[5] Dor Wilson,[3] Rhiannon Tudor Edwards,[1,2] Jane Noyes[1] and Dawn Craig[3]

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This report

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Abstract

Powered mobility interventions for very young children with mobility limitations to aid participation and positive development: the EMPoWER evidence synthesis

Nathan Bray[1,2*] Niina Kolehmainen[3,4] Jennifer McAnuff[3] Louise Tanner[3] Lorna Tuersley[2] Fiona Beyer[3] Aimee Grayston[5] Dor Wilson[3] Rhiannon Tudor Edwards[1,2] Jane Noyes[1] and Dawn Craig[3]

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Background: One-fifth of all disabled children have mobility limitations. Early provision of powered mobility for very young children (aged < 5 years) is hypothesised to trigger positive developmental changes. However, the optimum age at which to introduce powered mobility is unknown.

Objective: The aim of this project was to synthesise existing evidence regarding the effectiveness and cost-effectiveness of powered mobility for very young children, compared with the more common practice of powered mobility provision from the age of 5 years.

Review methods: The study was planned as a mixed-methods evidence synthesis and economic modelling study. First, evidence relating to the effectiveness, cost-effectiveness, acceptability, feasibility and anticipated outcomes of paediatric powered mobility interventions was reviewed. A convergent mixed-methods evidence synthesis was undertaken using framework synthesis, and a separate qualitative evidence synthesis was undertaken using thematic synthesis. The two syntheses were subsequently compared and contrasted to develop a logic model for evaluating the outcomes of powered mobility interventions for children. Because there were insufficient published data, it was not possible to develop a robust economic model. Instead, a budget impact analysis was conducted to estimate the cost of increased powered mobility provision for very young children, using cost data from publicly available sources.

Data sources: A range of bibliographic databases [Cumulative Index to Nursing and Allied Health Literature (CINHAL), MEDLINE, EMBASE™ (Elsevier, Amsterdam, the Netherlands), Physiotherapy Evidence Database (PEDro), Occupational Therapy Systematic Evaluation of Evidence (OTseeker), Applied Social Sciences Index and Abstracts (ASSIA), PsycINFO, Science Citation Index (SCI; Clarivate Analytics, Philadelphia, PA, USA), Social Sciences Citation Index™ (SSCI; Clarivate Analytics), Conference Proceedings Citation Index – Science (CPCI-S; Clarivate Analytics), Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH; Clarivate Analytics), Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects (DARE), NHS Economic Evaluation Database (NHS EED), Health Technology Assessment (HTA) Database and OpenGrey] was systematically searched and the included studies were quality appraised. Searches were carried out in June 2018 and updated in October 2019. The date ranges searched covered from 1946 to September 2019.

Results: In total, 89 studies were included in the review. Only two randomised controlled trials were identified. The overall quality of the evidence was low. No conclusive evidence was found about the effectiveness or cost-effectiveness of powered mobility in children aged either < 5 or ≥ 5 years. However, strong support was found that powered mobility interventions have a positive impact on children's movement and mobility, and moderate support was found for the impact on children's participation, play and social interactions and on the safety outcome of accidents and pain. 'Fit' between the child, the equipment and the environment was found to be important, as were the outcomes related to a child's independence, freedom and self-expression. The evidence supported two distinct conceptualisations of the primary powered mobility outcome, movement and mobility: the former is 'movement for movement's sake' and the latter destination-focused mobility. Powered mobility should be focused on 'movement for movement's sake' in the first instance. From the budget impact analysis, it was estimated that, annually, the NHS spends £1.89M on the provision of powered mobility for very young children, which is $< 2\%$ of total wheelchair service expenditure.

Limitations: The original research question could not be answered because there was a lack of appropriately powered published research.

Conclusions: Early powered mobility is likely to have multiple benefits for very young children, despite the lack of robust evidence to demonstrate this. Age is not the key factor; instead, the focus should be on providing developmentally appropriate interventions and focusing on 'movement for movement's sake'.

Future work: Future research should focus on developing, implementing, evaluating and comparing different approaches to early powered mobility.

Study registration: This study is registered as PROSPERO CRD42018096449.

Funding: This project was funded by the National Institute for Health Research (NIHR) Health Technology programme and will be published in full in *Health Technology Assessment*; Vol. 24, No. 50. See the NIHR Journals Library website for further project information.

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Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

List of abbreviations

BDI	Battelle Developmental Inventory
CASP	Critical Appraisal Skills Programme
CCG	Clinical Commissioning Group
EMPoWER	Early Mobility and POwered Wheelchair Evidence Review
EPIOC	electrically powered indoor–outdoor chair
GMFCS	Gross Motor Function Classification System
GRADE	Grading of Recommendations Assessment, Development and Evaluation
GRADE-CERQual	Grading of Recommendations Assessment, Development and Evaluation – Confidence in the Evidence from Reviews of Qualitative research
MERU	Medical Engineering Resource Unit
MMAT	Mixed Methods Appraisal Tool
ONS	Office for National Statistics
PEDI	Pediatric Evaluation of Disability Inventory
PPI	patient and public involvement
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	randomised controlled trial
RTI	Research Triangle Institute
STEM	science, technology, engineering and mathematics
TIDieR	Template for Intervention Description and Replication

Plain English summary

The aim of this study was to find out the benefits and costs of providing very young children, aged < 5 years, with powered mobility devices. Examples of powered mobility devices are electrically powered wheelchairs and modified ride-on toys.

We looked at many research papers about children and powered mobility. We found many benefits of powered mobility. We then combined all of the information to see if using powered mobility before the age of 5 years had any specific benefits for children.

The evidence tells us that powered mobility has a positive effect on children's movement, and it can boost children's social interactions with other people, and their independence. Children using powered mobility were able to go to their friends by themselves, move around a play space as they wanted and take part in physical activities and games.

We found that the fit between the child, the powered mobility device and the child's everyday environment was important. When the fit was not good, children experienced a lot of problems. Some children and families felt that powered mobility did not suit their needs, leading to children using a manual wheelchair instead and thereby missing out on education, social opportunities and play. Barriers to powered mobility were found in the physical environment (e.g. inaccessible buildings) and the social environment (e.g. adults supervising children too closely) and often affected children's independence.

We found that the advantages and disadvantages of powered mobility were similar in younger and older children, even though the activities they took part in were different. We also found that each year the NHS spends < 2% of its wheelchair service budget on powered mobility for very young children.

In conclusion, powered mobility can benefit very young children, but it requires a good fit with the child's environment.

Scientific summary

Background

Mobility impairment is the leading cause of disability in the UK, accounting for 49% of reported disabilities. Around 8% of children in the UK have a disability, equating to 1.1 million disabled children. Of this number, 19% are estimated to have some form of mobility limitation. The ability of public services, including health and social care and education, to improve the life of children with mobility limitations is currently significantly hindered by a lack of effective interventions. The patients, policy-makers and health-care providers all agree that improving interventions is an urgent priority.

Early provision of powered mobility for very young children (aged < 5 years) may help to enable self-directed movement in children who are limited in their movements or unable to move, and could consequently trigger positive developmental changes, similar to crawling. This, in turn, could facilitate exploration, learning and further development. Children with mobility limitations have less self-directed movement than their typically developing peers, with fewer opportunities for exploration of the world around them. This places the children at greater risk of secondary disabilities in terms of general independence, autonomy and participation in daily life across home, education and leisure. It is thought that early powered mobility could prevent these secondary disabilities developing by enabling self-directed mobility and exploration.

Powered mobility interventions are complex interventions with several elements and synergistic outcomes and benefits. The use of powered mobility takes place in, and is influenced by, the child's physical and social environment, and the exact features and delivery of the intervention elements vary depending on a child's age and/or developmental stage and impairments.

The NHS provides mobility equipment for ≈ 60,000 children each year. However, the current provision of powered mobility interventions commonly focuses on children aged > 5 years, with the assumption that very young children do not benefit from it, at least not sufficiently for it to be cost-effective. If the hypotheses about the role of early self-directed mobility in the prevention of secondary problems are true, then current provision is likely to be a missed opportunity to improve the outcomes of children with disabilities and yield the best returns for public resource across the life course. The key remaining question is whether or not early provision (i.e. before the age of 5 years) is incrementally more effective and cost-effective than later provision (i.e. from the age of 5 years onwards).

Objectives

The research question was as follows: is the earlier provision of powered mobility to very young children more cost-effective than currently more common provision to children aged ≥ 5 years?

The aim was to examine and model the relative effectiveness and cost-effectiveness of powered mobility interventions for very young children with mobility limitations, compared with the more

common practice of powered mobility provision for children aged ≥ 5 years. To do so, the following key objectives were defined:

- to identify and synthesise quantitative, qualitative and mixed-method evidence to determine –
  - the effectiveness and cost-effectiveness of powered mobility interventions for children with mobility limitations, and the wider impacts on health services and society
  - the acceptability, feasibility and anticipated outcomes of relevant interventions from multistakeholder perspectives (e.g. children, parents, service providers and commissioners)
  - the long-term implications of self-directed or independent mobility for very young children (aged < 5 years), compared with older children (aged ≥ 5 years)
- to examine the economic costs and benefits of powered mobility interventions for children by –
  - building tariffs of NHS and non-NHS costs for powered mobility interventions (equipment, training and support, and any other components) for children with mobility limitations using a multiperspective disaggregated cost–consequence framework
  - modelling the relative cost-effectiveness of powered mobility equipment for very young children (aged < 5 years), compared with standard NHS practice (provision of such equipment for children aged ≥ 5 years).

Methods

This study was planned as a mixed-methods evidence synthesis and economic modelling study, incorporating quantitative, qualitative, mixed-methods and economic evidence. The key intended outputs were an overview of the current evidence of powered mobility interventions for children; a logic model of effectiveness and cost-effectiveness for planning and evaluating future interventions and commissioning of services; an economic model, budget impact analysis and value-of-information analysis for early powered mobility; and recommendations for powered mobility provision and for future research.

The initial programme theory, developed in the form of a novel logic model, was utilised as a conceptual starting point and was refined throughout the review processes to produce a definitive logic model. The active intervention was provision of powered mobility for children aged < 5 years, and the comparator was provision of powered mobility for children aged ≥ 5 years. The systematic review protocol was registered on PROSPERO as CRD42018096449.

Review 1: effectiveness and cost-effectiveness of powered mobility for children

We reviewed evidence relating to the effectiveness, cost-effectiveness, acceptability, feasibility and anticipated outcomes of paediatric powered mobility interventions, integrating a range of perspectives (children, parents, service providers, commissioners, society).

To identify relevant literature, we systematically searched a range of bibliographic databases [Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE, EMBASE™ (Elsevier, Amsterdam, the Netherlands), Physiotherapy Evidence Database (PEDro), Occupational Therapy Systematic Evaluation of Evidence (OTseeker), Applied Social Sciences Index and Abstracts (ASSIA), PsycINFO, Science Citation Index (SCI; Clarivate Analytics, Philadelphia, PA, USA), Social Sciences Citation Index™ (SSCI; Clarivate Analytics), Conference Proceedings Citation Index – Science (CPCI-S; Clarivate Analytics), Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH; Clarivate Analytics), Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects (DARE), NHS Economic Evaluation Database (NHS EED) and Health Technology Assessment (HTA) Database; searches covered 1946 to September 2019], reference lists of included papers, relevant journals and conference proceedings, and grey literature. For the search

terms, we used a combination of three facets: 'children', 'powered mobility' and 'independent mobility'. The searches were not restricted by outcome, disability/condition, study design, language or publication year. Papers were included if all three of the following criteria were met: (1) the study participants included children with significant mobility limitations defined using explicit criteria, (2) the intervention involved at least one of the five explicitly defined intervention elements and (3) the outcome (or the 'phenomenon of interest') was related to the child, their family, health or social care, or education. The searches were carried out in June 2018 and updated in October 2019.

Titles and abstracts were screened for inclusion by two independent reviewers, of which at least one was a topic expert; studies judged as being relevant were obtained as full texts. Methodological strengths and limitations of included studies were assessed using a range of tools, with focus on risk of bias in randomised controlled trials, risk of bias and confounding in non-randomised studies and risks to rigour in qualitative studies. A range of numeric and textual data were extracted from all included papers using a bespoke extraction form similar to previous reviews.

Two syntheses were carried out to make best use of the extracted evidence. First, we undertook a convergent mixed-methods evidence synthesis using a framework synthesis method. In this, textual and numeric data across studies were integrated to identify and develop key concepts relevant to the intervention, its outcomes, and feasibility and acceptability. We applied selected, mixed-methods-specific criteria to assess certainty of the evidence underpinning the resulting concepts. Second, we undertook a separate qualitative evidence synthesis using the Thomas and Harden (Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Med Res Methodol* 2008;**8**:45) method of thematic synthesis. Findings in primary qualitative and relevant mixed-methods studies were translated and then transformed to look for new patterns and meanings that were not seen in individual primary studies. We subsequently applied the Grading of Recommendations Assessment, Development and Evaluation – Confidence in the Evidence from Reviews of Qualitative research (GRADE-CERQual) approach to assess the confidence in synthesised qualitative findings. The results from the two syntheses were subsequently compared and contrasted, and further integrated to develop a final, revised logic model for evaluations of effectiveness and cost-effectiveness of powered mobility interventions.

Review 2: long-term implications of independent mobility

A second systematic review, to identify evidence relating to the long-term implications of self-directed or independent mobility for very young children, compared with the implications for older children, used two broad facets to identify relevant papers: (1) independent mobility and (2) children or young people. The search resulted in > 47,000 potential papers; however, despite several attempts to identify relevant papers, we were unable to identify key papers relevant to the aim and had to conclude that it was not possible to systematically identify research studies related to the long-term implications of self-directed and independent mobility.

Economic modelling and budget impact analysis

The original intention was to develop an economic model to examine the long-term cost-effectiveness of early powered mobility. However, after the completion of the reviews, it became apparent that there were insufficient published data to develop a robust economic model or to carry out a value-of-information analysis.

As an alternative, we conducted a budget impact analysis (following International Society for Pharmacoeconomics and Outcomes Research guidance) to model the cost of current practice and those of hypothetical scenarios of increased access to powered mobility for children aged < 5 years. Cost data were generated from publicly available publications, and through consultation with NHS posture and mobility services, the National Wheelchair Managers Forum, charitable organisations, various wheelchair manufacturers and expert advisors to the project. A range of different direct costs were considered, including mobility equipment, accessories/modifications, repair/maintenance, training, home/vehicle adaptations and staff time.

Results

Review 1

We identified 5948 potentially relevant titles and abstracts, from which 221 were included in full-text screening. A further 16 relevant publications were identified from reference lists and 30 from the grey literature, and 50 were recommended by expert advisors; this resulted in a total of 317 publications for full-text screening. Of these, 89 publications (covering 89 studies) met the inclusion criteria.

The included studies comprised two randomised controlled trials; 18 qualitative studies; three mixed-methods studies; and 66 studies of other designs, such as observational and non-randomised trials. Nearly one-third of the studies were single subject studies, which often consisted of case reports or clinical cases.

Of the included studies, 39% reported data specifically for children aged < 5 years, and 28% for children aged ≥ 5 years. Half of the included studies described multiple diagnoses, and, overall, the studies covered a broad range of diagnoses. For the included quantitative studies, there were substantial concerns about the lack of control for potential confounding. For the qualitative and mixed-methods studies, all were judged to have used appropriate overall methodologies, but all had some form of methodological limitation.

Across the included studies, 70% investigated powered mobility equipment, 22% investigated powered mobility training and 8% investigated a combination of equipment and training. None explicitly investigated environmental or policy adaptations.

We found no conclusive evidence about the effectiveness or cost-effectiveness of powered mobility for children aged either < 5 or ≥ 5 years. However, the mixed-methods synthesis of all evidence, and an assessment of certainty of that evidence, found strong support that powered mobility interventions have a positive impact on children's movement and mobility, and moderate support for a positive impact on children's participation, play and social interactions, and on the safety outcome of accidents and pain. Limited support was found for the concepts of self-care, autonomy, choice/control, freedom and psychological consequences (i.e. confidence, motivation and cognition). Limited support was also found for the safety outcome of emotional consequences (positive and negative feelings for the parent or the child), and inconsistent support was found for children learning to drive powered mobility.

The qualitative synthesis provided further insights, particularly regarding the implementation, feasibility and acceptability of powered mobility for children (for both very young and older children). We found the acceptance of powered mobility to be a journey for both parents and children, and the child's development of powered mobility skills to be a continuum that was supported by experiential learning and play. In this journey, it appears to be important for parents and therapists to invest their time and provide the child with support for the intervention to have full impact. Similarly to the mixed-methods synthesis, the fit between the child, the equipment and the environment was found to be important, as were the outcomes related to a child's independence, freedom and self-expression.

Budget impact analysis

We estimate that, each year, £2.84M is spent on the provision of powered mobility to very young children in the UK. Of this, £1.89M is spent by the NHS, which is $< 2\%$ of the total current wheelchair service spend of the NHS. If the provision of powered mobility were to increase and the NHS were to take on third-sector provision/training, this would rise to £5.64M, or 5.2% of current wheelchair service spend, and cover 1375 very young children.

Conclusions and recommendations

The evidence supported two key, distinct ways of conceptualising the primary powered mobility outcome: movement and mobility. First is 'movement for movement's sake' (e.g. play, exploring, acting on the environment, autonomy, misbehaving, cognition and learning). This is relevant to all children, regardless of physical or cognitive ability, and appears to be the primary function of early powered mobility. In this, two further outcome chains are implied: (1) developmental benefits achieved through movement and (2) preparing children for becoming powered wheelchair users. Of these, the former is relevant to all children, whereas the latter can be difficult to prospectively judge in terms of which children this applies to.

Second is destination-focused mobility (e.g. getting from A to B, which is a key mechanism of participating at home, in education, in the community). This is essentially the conceptualised purpose of adult powered wheelchairs; although the review did find evidence of the importance of this dimension for children, it was only one of the two dimensions, and not always the most important one, especially for the very youngest of children. These two conceptualisations of powered mobility outcomes suggest that the provision of early powered mobility should not be considered through the same framework as provision of adult powered mobility, nor should it be treated as a stepping stone to powered wheelchair use. Instead, a key criterion for provision should include the potential of powered mobility to enable a child to move – for movement's sake or for the child to go from A to B – in order to promote the child's development, play, exploration and independence.

We further conclude that age is not the key factor in paediatric powered mobility provision. There are few data to support the restriction of powered mobility provision by age. Instead, the focus should be on providing powered mobility interventions in a developmentally appropriate manner, focusing on 'movement for movement's sake' in the first instance and establishing good 'fit' between the child, the powered mobility equipment and the child's environment (both physical and social). Therefore, comparing powered mobility effectiveness and cost-effectiveness before and after the age of 5 years may not be informative, because these interventions are likely to have different aims, purposes and conceptualisations.

Current NHS provision of early powered mobility covers only a limited proportion (50% at most) of very young children who could benefit from early powered mobility, with third-sector providers filling the gap in provision. Even if the NHS was to double provision of early powered mobility and take on third-sector provision, the costs would remain a small fraction of overall wheelchair service expenditure.

Study registration

This study is registered as PROSPERO CRD42018096449.

Funding

This project was funded by the National Institute for Health Research (NIHR) Health Technology programme and will be published in full in *Health Technology Assessment*; Vol. 24, No. 50. See the NIHR Journals Library website for further project information.

Chapter 1 Introduction

Background

Non-communicable illness and disability are responsible for most health expenditure in Western countries. Mobility impairment is the leading cause of disability in the UK, accounting for 49% of reported disabilities.[1] Around 8% of children in the UK have a disability, equating to 1.1 million disabled children (aged 0–19 years). Of this number, 19% are estimated to have some form of mobility limitation, which equates to approximately 209,000 UK children with mobility limitations.[1] The ability of public services, including health and social care and education, to improve the life of children with mobility limitations is currently significantly hindered by a lack of effective interventions.[2–6] Patients, policy-makers and health-care providers all agree that improving interventions is an urgent priority.[7,8]

One of the most promising interventions is the early provision of powered mobility for very young children (aged < 5 years) with mobility limitations. Early powered mobility interventions enable self-directed movement in children who are limited in their movements or unable to move, and is consequently thought to trigger positive developmental changes, similar to crawling.[9–13] The idea of early powered mobility as an intervention is based on the observation that acquisition of self-directed mobility (e.g. through rolling, crawling, bottom-shuffling) results in a major step change in children's engagement with the world and, through that, in their perceptual, cognitive, social and physical development. Children with mobility limitations have less self-directed movement than their typically developing peers, with fewer opportunities for exploration of the world around them.[12–16] This places children with mobility limitations at a greater risk of secondary disabilities in terms of life skills (motor, cognitive, social abilities related to daily tasks); general independence and autonomy; and participation in daily life across home, education and leisure.[16,17] These secondary disabilities are hypothesised to be negatively related to a child's long-term health, development and social integration, as well as having a negative impact on parental physical and mental health, parental productivity and wider society. Early powered mobility could prevent these secondary disabilities by enabling self-directed mobility and exploration, and subsequent developmental benefits.

Powered mobility interventions are complex interventions with several elements and synergistic outcomes and benefits. The use of powered mobility takes place in, and is influenced by, a child's physical and social environment,[11] and the exact features and delivery of the intervention elements varies depending on the child's age and/or developmental stage and impairments. Provision of powered mobility often involves allied health (e.g. physiotherapy, occupational therapy) and wheelchair services coming together to enable the provision of multifaceted intervention packages. Examples of intervention elements included in such packages are as follows:

- the powered mobility equipment, for example powered wheelchair, ride-on device or toy car, to enable the child to move around, including any related method of control (e.g. switches)
- training and other behaviour change techniques, for example goal-setting and self-monitoring, provided to the child and the people around the child to maximise the likelihood that the equipment is used regularly and appropriately
- adaptations to physical environment, for example ramps and lifts, to enable the physical use of the equipment
- adaptations to policies and practices, for example safety rules and activity processes, to provide a socially facilitative and safe environment for the use of the equipment
- maintenance and reviewing, for example maintenance of the equipment and related adaptations and use, in the longer term.

There are currently no agreed standardised descriptions for any of these elements.

Provision of mobility equipment to children is not new. For example, > 60,000 children are registered with NHS posture and mobility services.[18] However, the current provision of powered mobility interventions commonly focuses on children aged ≥ 5 years, with an implicit assumption that most children aged < 5 years do not benefit from it, at least not sufficiently for it to be cost-effective. This assumption may be based on a number of preconceptions about the abilities of very young children to safely use powered mobility, the purpose of powered mobility and the adequacy of other interventions (i.e. buggies and manual wheelchairs) to fulfil the needs of these children.

If the hypotheses about the role of early self-directed mobility in prevention of secondary problems are true, then the current provision may be a missed opportunity to yield the best returns for public resource across the life course.[19] The key remaining question is whether or not early provision of powered mobility is incrementally more effective and cost-effective than later provision (i.e. from the age of 5 years onwards).

There is currently no evidence-based national guidance, or other up-to-date evidence summary, for decision-makers on what is the optimal time point for powered mobility provision for children, how different intervention components relate to cost-effectiveness, how variability in children's conditions and diagnoses influences effectiveness or what outcomes could be used to monitor benefits of provision. In the absence of guidance or summary, the provision of powered mobility provision is highly variable across services and regions. This further exacerbates the socioeconomic, health and well-being inequalities already experienced by children with mobility limitations and their families.

The aim of this project was to synthesise the existing evidence about the relative benefits and cost-effectiveness of early powered mobility (for children aged < 5 years) compared with later powered mobility (children aged ≥ 5 years) in both the short and long term. We hope to provide health commissioners, wheelchair services, service providers more broadly (both in the NHS and beyond), policy-makers and families with access to timely evidence to facilitate better-informed decisions about how best to use resources to support disabled children and to promote their long-term health and well-being.

From scoping of the literature and from expertise in the team, including the wider project advisory group, an upfront logic model was developed, following published guidance and examples.[20,21] The logic model was developed to provide a simplified representation of the proposed key outcomes and related change processes for powered mobility interventions (*Figure 1*).

The literature and expert opinion propose that provision of powered mobility interventions for very young children will reduce the negative effects of mobility limitations by enabling self-directed mobility, which provides opportunities for exploration and the development of a child's life skills,[13,17,22] independence,[13,23] autonomy and participation in daily life.[11,24] It is further proposed that these will collectively enhance the child's long-term health, development and social integration, [11,22,24] and that subsequent developmental gains will reduce a child's need for parental support[14] and reduce related parental stress.[15] A further suggestion, derived from the literature and expert opinion, is that child and parent gains may, together, reduce the burden on public services across health, education and social care.

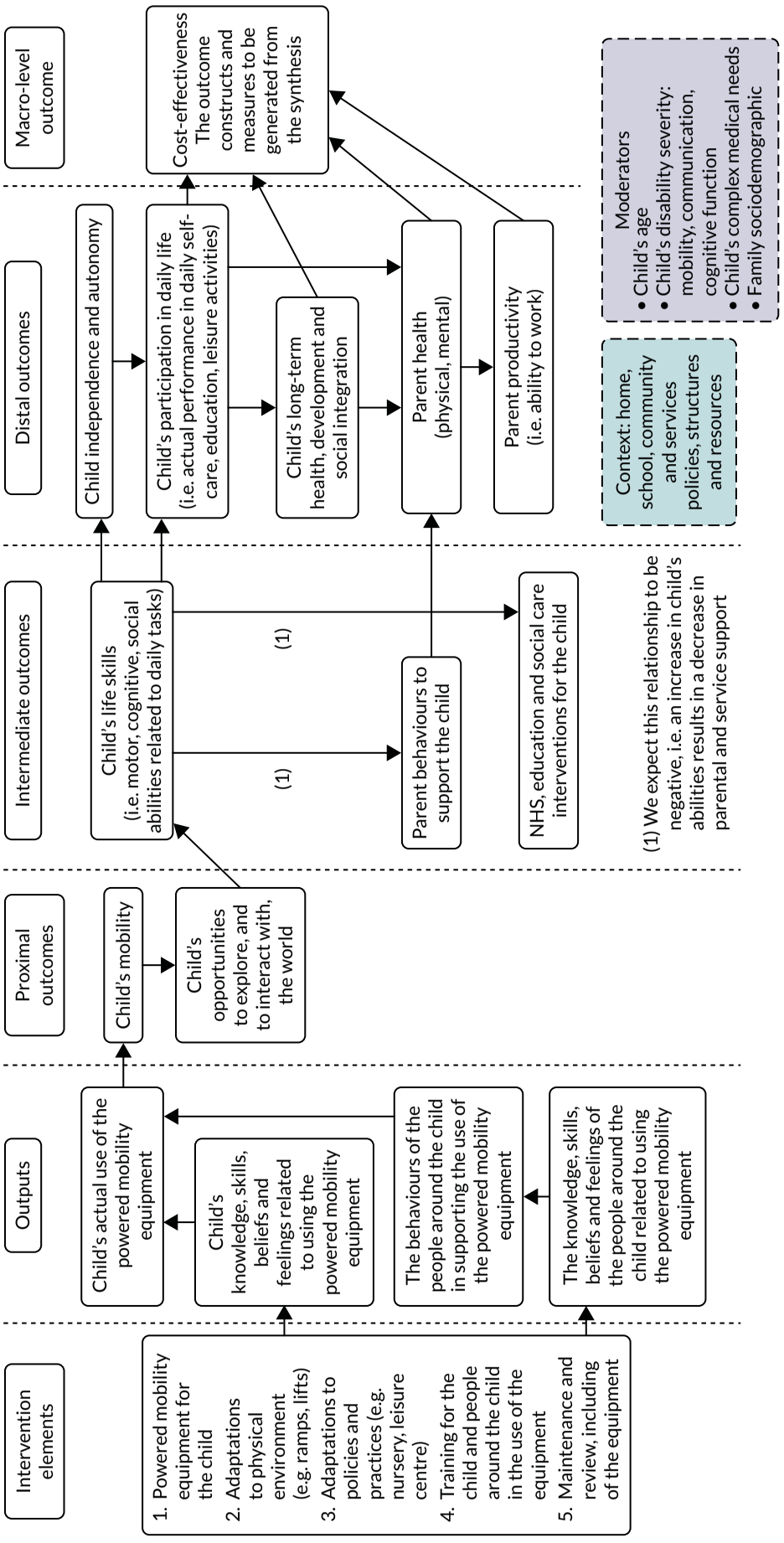

FIGURE 1 Initial logic model to be used as a framework for the evidence synthesis of the effectiveness and cost-effectiveness of powered mobility for children with mobility limitations. The green box indicates the context and the purple box indicates the moderators.

Chapter 2 Research question and aims

The research question was as follows: is the earlier provision of powered mobility to very young children more cost-effective than currently more common provision to children aged ≥ 5 years?

The aim was to examine and model the relative effectiveness and cost-effectiveness of powered mobility interventions for very young children (aged < 5 years) with mobility limitations, compared with the more common practice of powered mobility provision for children aged ≥ 5 years. To do so, the following of key objectives were defined:

- to identify and synthesise quantitative, qualitative and mixed-method evidence to determine –
    - the effectiveness and cost-effectiveness of powered mobility interventions for children with mobility limitations, and the wider impacts on health services and society
    - the acceptability, feasibility and anticipated outcomes of relevant interventions from multistakeholder perspectives (children, parents, service providers, commissioners, etc.)
    - the long-term implications of self-directed or independent mobility for very young children (aged < 5 years) compared with older children (aged ≥ 5 years).
- to examine the economic costs and benefits of powered mobility interventions for children by –
    - building tariffs of NHS and non-NHS costs for powered mobility interventions (equipment, training and support, and any other components) for children with mobility limitations using a multiperspective disaggregated cost–consequence framework
    - modelling the relative cost-effectiveness of powered mobility equipment for very young children (aged < 5 years), compared with standard NHS practice (provision of such equipment for children aged ≥ 5 years).

Chapter 3 Overall design

Methodology

The Early Mobility and POwered Wheelchair Evidence Review (EMPoWER) study was planned as a mixed-methods evidence synthesis and economic modelling study, incorporating quantitative, qualitative, mixed-methods and economic evidence. The key intended outputs were an overview of the current evidence of powered mobility interventions for children; a logic model of effectiveness and cost-effectiveness for planning and evaluating future interventions and commissioning of services; an economic model, budget impact analysis and value-of information analysis for early powered mobility; and recommendations for powered mobility provision and for future research. To achieve the objectives and deliver the outputs, we planned a number of inter-related research activities:

- a systematic review of evidence relating to the effectiveness, cost-effectiveness, acceptability, feasibility and anticipated outcomes of paediatric powered mobility interventions, integrating a range of perspectives (children, parents, service providers, commissioners, society)
- a further second review of available evidence on the long-term implications of self-directed or independent mobility for very young children (aged < 5 years), compared with the implications for older children (aged ≥ 5 years)
- the development of cost tariffs of NHS and non-NHS costs for powered mobility interventions (equipment, training and support, and any other components) for children with mobility limitations using a multiperspective disaggregated cost–consequence framework
- an economic model to facilitate a comparison of the relative cost-effectiveness of powered mobility equipment for very young children with standard NHS practice of powered mobility provision for older children
- an integrative overall synthesis of learnings from across these listed activities in order to develop a new model for assessing the effectiveness and cost-effectiveness of early powered mobility interventions.

Population

The overall study population was children with mobility limitations, defined as limitations in a child's ability to move around in space. In existing literature, mobility limitations have been described using standardised classification systems [e.g. the Gross Motor Function Classification System (GMFCS)]; codes from the World Health Organization's International Classification of Functioning, Disability and Health (ICF);[25] or clinical observations. Certain medical diagnoses have also been used as indicative proxies for a presence of mobility limitations; for example, a diagnosis of cerebral palsy is indicative of mobility limitations, but it is well recognised that medical diagnoses alone do not provide precise estimates of a child's capacity for movement. Use of ability-based, as opposed to diagnosis-based, approaches to defining study populations is recommended to reflect the realities of the children and service provision, and thus to support external validity and relevance to the NHS setting.[26,27] In terms of children with mobility limitations, the focus of the present study was on a comparison between children aged < 5 years and children aged ≥ 5 years.

Setting

The settings of interest included any high-income health and social care provision, family contexts and nurseries, education, and communities broadly similar to UK. We anticipated the most common provider setting to be allied health and wheelchair services providing mobility interventions for children, as well as third-sector providers.

The health technology

As a starting point, the intervention of interest, early powered mobility, was defined as consisting of five elements: the powered mobility equipment, adaptations to physical environment, adaptations to policies and practices, training and other behaviour change techniques, and maintenance and reviewing. We anticipated that the review would inform this conceptualisation further, and potentially re-shape it.

Stakeholder involvement

This study contributed to addressing two of the 10 key research questions prioritised by users and providers of children's neurodisability services in the James Lind Alliance Research Priority Setting Partnership for childhood disability:[7]

> *Does appropriate provision of wheelchairs to enable independent mobility for very young children improve their self-efficacy? [Question 1.]*
>
> *Does the timing and intensity of therapies . . . alter the effectiveness of therapies for infants and young children with neurodisability, including those without specific diagnosis? What is the appropriate age of onset/strategies/dosage/direction of therapy interventions? [Question 4.]*
>
> *Morris* et al.[7] *Published by the BMJ Publishing Group Limited. This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/*

The overall aim was to optimise the relevance, usefulness and potential impact of the study by integrating expertise and insight from expert stakeholders at each stage. Patient and public involvement (PPI) was integrated with and embedded within a wider stakeholder involvement strategy; thus, we refer to stakeholder involvement rather than PPI. We took a comprehensive and 'real-world' approach to stakeholder analysis, identifying individuals and organisations with an interest in the study or who could be affected by the study. This included, but was not limited to, service users (i.e. children, young people, and parents). To achieve substantial and meaningful stakeholder involvement, we used a multipronged approach. First, we engaged an expert service user (AG) as a co-investigator from the outset of developing the project. Aimee Grayston has considerable lived experience of using powered mobility in the context of complex mobility and communication limitations, and was already collaborating with two study team members (JM, NK). Her role at the grant application stage was to help develop the up-front logic model (see *Figure 1*), to advise on the design and projected costs of involvement activities and to respond to selected comments from reviewers. Throughout the study, Aimee Grayston attended study meetings, teleconferences and co-production workshops and engaged in study methods. She guided the wider team's thinking on the conceptualisation of intervention components, outcomes and the acceptability/feasibility of powered mobility implementation. Her contributions sensitised the team to key ideas and influenced how we conducted the project and revised the logic model. In the end stages of the project, Aimee Grayston developed the plain language summary and provided feedback on the draft report, and will continue to aid in the dissemination of findings.

Second, we convened an international project advisory group consisting of researchers, service providers/managers, service commissioners, policy advisors, commercial directors, representatives of national charitable organisations, and parents of children and young people with mobility limitations (see *Appendix 1*, *Table 39*, for a full list of members). We purposefully integrated professional and parent advisors for three reasons: (1) we wanted to centrally embed service user involvement in the wider stakeholder involvement strategy; (2) we were equally as invested in benefiting from professional

and service user expertise; and (3) from our prior experiences of PPI in this field, we had learned that many professionals and service users place high value on coming together to share perspectives and experiences. We identified group members on the basis of their wide-ranging expertise in the development, implementation, benefits and costs of powered mobility interventions, and their experience of powered mobility in diverse health service, third-sector and commercial contexts. *Appendix 1*, *Table 39*, sets out the particular expertise brought by each individual advisor. We approached the professional advisors directly, and the parent advisors were a combination of existing collaborators of the study team and new collaborators recruited through the charitable organisation Designability.

The advisory group was consulted about a wide range of different topics and we called on it at different time points for different purposes, depending on the fields of expertise of various members. Contact was generally informal, and conducted through e-mails, face-to-face meetings and telephone/video calls. Several specific examples of the advisory group's involvement are cited throughout this report. The advisors helped to shape the up-front logic model (particularly parents); develop the search strategies; identify key evidence and grey literature; keep up to date with the most recent publications; clarify redundancy and overlap in the literature (particularly researchers, policy advisors and representatives of charitable organisations); and understand and resolve conceptual issues, particularly regarding the long-term implications of self-directed or independent mobility for very young children (particularly researchers). They also helped to inform our understanding and interpretation of the data relating to the feasibility, acceptability, costs and benefits of early powered mobility (particularly parents, service providers/managers and commissioners), and we worked directly with some advisors to identify cost data for the economic analysis (particularly service providers/managers, service commissioners, commercial directors and representatives of charitable organisations). All of this fed directly into how we refined the up-front logic model and the acceptability and clarity of the key messages. The advisors also helped to maintain a public-facing presence for the study in the clinical, research and service user communities, through signposting and discussion on their own social media platforms and at professional conferences. After publication of the report, the group will continue to support the research team by offering potential opportunities for implementation of practice-related recommendations.

Third, we worked with AniMates, a young people's involvement group that specialises in making artwork to shape and share research[28] (*Figure 2* presents an example of the artwork the group generated for the EMPoWER project). AniMates comprises young people and artists aged 16–21 years, an interdisciplinary artist and a researcher. AniMates members have experience of living with physical, communication or learning disabilities or of supporting people who live with disabilities. Three members use powered

FIGURE 2 Artwork produced as part of the EMPoWER workshops.

mobility themselves. AniMates enabled the project team to include the views of young powered mobility users and to find creative ways to explain the project and disseminate the findings. Five workshops were held during the project, each facilitated by a member of the research team and an artist. AniMates helped to interpret the emerging results and their relative importance, and challenged the research team's understanding and assumptions. Their contribution fed into the final logic model and also facilitated creative, engaging dissemination plans.

The research team provided parent and young person advisors with informal training to prepare them for being involved in the study. For parents, this was in the form of accessible written materials explaining key concepts in the study (e.g. cost-effectiveness, systematic review methods) and an extended face-to-face meeting with one researcher to go through the materials, discuss the up-front logic model, and share experiences and ideas about powered mobility interventions. For the young people, informal training was in the form of two workshops, facilitated by a researcher and an artist, exploring the rationale for the study, key concepts, and their roles, rights, and responsibilities as advisors. The contribution of the adult advisors (i.e. the parents and AG) was acknowledged in the form of payments or gift vouchers based on established guidance from INVOLVE.[29] The contribution of young people was similarly acknowledged, based on established guidance about national minimum wage and national living wage rates.[30] Reporting of PPI and stakeholder involvement is summarised in *Appendix 2*.

Chapter 4 Review 1: a mixed-methods review of the effectiveness, cost-effectiveness, perceived outcomes, acceptability and feasibility of powered mobility

This chapter reports on the first review conducted to explore the effectiveness, cost-effectiveness, acceptability, feasibility and anticipated outcomes of powered mobility interventions, integrating a range of perspectives (children, parents, service providers, commissioners, society, etc.). Therefore, this chapter addresses two of the stated aims; specifically, to determine:

1. the effectiveness and cost-effectiveness of powered mobility interventions for children with mobility limitations, and the wider impacts on health services and society
2. the acceptability, feasibility and anticipated outcomes of relevant interventions from multistakeholder perspectives (children, parents, service providers, commissioners, etc.).

Methods

The initial programme theory in the logic model (see *Figure 1*) was utilised as a conceptual starting point and was refined throughout the review processes to produce a definitive logic model. The active intervention was provision of powered mobility for children aged < 5 years (i.e. early powered mobility), and the comparator was provision of powered mobility for children aged ≥ 5 years.

Before the review, we anticipated finding limited evidence on effectiveness from formal evaluations such as randomised controlled trials (RCTs), and anticipated that evidence on different types of outcomes (effectiveness, cost-effectiveness) and phenomena of interest (feasibility and acceptability) would be spread across papers. Therefore, we expected to use a mixed-methods review design utilising a variety of synthesis methods. After the search and screening had been completed and the actual body of included papers was known, the specific overall mixed-methods design was decided on.

Processes for searching and for quality appraisal followed the basic principles for conducting effectiveness and cost-effectiveness reviews,[31] using additional up-to-date relevant methods and tools, with an explicit protocol registered with PROSPERO as CRD42018096449.[32] With the papers and evidence ultimately identified (see *Results: an overview of evidence of powered mobility interventions for children*) it was not possible to undertake a meta-analysis. We therefore undertook two types of synthesis to make best use of the available evidence. First, we undertook a convergent data-based, mixed-methods evidence synthesis, using a framework synthesis method, in which textual and numeric data from all included studies (quantitative, qualitative and mixed-methods designs) were analysed and synthesised concurrently in a complementary manner.[33,34] The use of framework synthesis enabled findings from all included studies to be synthesised around common concepts that were derived from the included studies, with regular checking-back to the review question and the initial logic model. We subsequently assessed the certainty of evidence using mixed-methods-specific criteria.

Second, we undertook a separate qualitative evidence synthesis using the Thomas and Harden[35] method of thematic synthesis. This method includes three stages: line-by-line coding, development of descriptive themes, and then development of analytical-level themes. The development of analytical-level themes was important to provide new insights that went beyond findings presented in the primary studies. Findings in primary studies were translated and then transformed to look for new patterns and meanings that were not seen in individual primary studies. We subsequently applied the Grading of Recommendations

Assessment, Development and Evaluation – Confidence in the Evidence from Reviews of Qualitative research (GRADE-CERQual)[35] approach to assess the confidence in synthesised qualitative findings.

The initial logic model evolved during the course of the syntheses as the evidence became known and understood. The service user co-investigator (AG) and the project advisory group were instrumental in the continuous review and critique of the logic model, for example by challenging its assumptions and gaps, and enabling the research team to better understand and convey relationships between powered mobility interventions and outcomes. Care was taken to differentiate between evidence, expert/lay opinion and proposition/conjecture when populating the logic model. We then used the evolving logic model as the framework for integrating the various syntheses and drawing out the relevant evidence to address the original review question and objectives.

The following section reports the search strategy and methods for screening, quality appraisal and general data extraction, which were all undertaken once, but which fed into both synthesis approaches. The two syntheses and approaches to grading the bodies of evidence are then described in more detail, separately, for each synthesis approach.

Search strategy

To identify relevant literature to inform the first review, a search strategy was designed and run in collaboration with an experienced information specialist. The search was designed to prioritise sensitivity over specificity, and was structured according to the facets of 'children', 'powered mobility' and 'independent mobility'. For each facet, the search incorporated both thesaurus-controlled subject heading terms and text words or phrases. A full list of search terms is presented in *Table 1*. For an illustrative example of keywords

TABLE 1 Search terms for review 1

Search term	Proximity	Proximal search term
Facet 1: children		
child(ren) or adolescent (ce) or teen(s)/(ager(s)) or youth(s) or girl(s) or boy(s) p(a)ediatric(s) or juvenile(s) or infant(s) or "young people" or "young person" or "young adult" or "young men" or "young women" or schoolchild(ren)		
Facet 2: powered mobility		
power(ed)	within five words of	(wheel)chair(s)
electric(al)		pushchair(s)
motorised (zed)		equipment
assist(ed)		car(s)
		scooter(s)
		toy(s)
		mobility
		buggy/ies
Facet 3: independent mobility		
independent(ly)	within three words of	Mobile
self*		mobility
autonomous		move*/moving
		walk(ing)
		crawl(ing)

and a search strategy, see *Appendix 3*. The searches were not restricted by outcome, disability, activity limitation or medical condition, as these were incorporated at the screening stage, nor by study design, language or publication year.

The following bibliographic databases were searched in June 2018; searches were updated in early October 2019:

- Cumulative Index to Nursing and Allied Health Literature (CINAHL) (via EBSCO*host*; EBSCO Information Services, Ipswich, MA, USA), 1980 to September 2019
- MEDLINE (via Ovid®; Wolters Kluwer, Alphen aan den Rijn, the Netherlands), 1946 to September 2019
- EMBASE™ (Elsevier, Amsterdam, the Netherlands) (via Ovid), 1980 to September 2019
- Physiotherapy Evidence Database (PEDro), 1999 (inception) to September 2019
- Occupational Therapy Systematic Evaluation of Evidence (OTSeeker), 2001 (inception) to September 2019
- Applied Social Sciences Index and Abstracts (ASSIA) (via ProQuest®; ProQuest LLC, Ann Arbor, MI, USA), 1987 to September 2019
- PsycINFO (via Ovid), 1967 to September 2019
- Science Citation Index and Social Sciences Citation Index™ (Clarivate Analytics) (via Web of Science™; Clarivate Analytics), 1970 to September 2019
- Conference Proceedings Citation Index – Science (Clarivate Analytics), and (Clarivate Analytics, Philadelphia, PA, USA) Conference Proceedings Citation Index – Social Science & Humanities (Clarivate Analytics) (via Web of Science), 1990 to September 2019
- Cochrane Central Register of Controlled Trials (CENTRAL) and Cochrane Database of Systematic Reviews (via the Cochrane Library), 1995 (inception) to September 2019
- Database of Abstracts of Reviews of Effects (DARE) and NHS Economic Evaluation Database (NHS EED) (via the Cochrane Library), 1994 (inception) to May 2015
- Health Technology Assessment (HTA) Database (via the Cochrane Library), 1998 (inception) to September 2019.

To reduce publication bias, the electronic searches were supplemented by reference list searching: hand-searching a sample of selected, highly relevant journals (i.e. *Clinical Rehabilitation*, *Archives of Physical Medicine and Rehabilitation* and *Disability and Rehabilitation: Assistive Technology*); searching any highly relevant conference proceedings that were not indexed on the databases listed previously; and identification of relevant grey literature. Grey literature searching included OpenGrey and resources such as government policy documents, third-sector organisation reports and unpublished research, much of which was sourced from within the project advisory group, particularly from the researchers and policy advisors. The project advisory group also directed us to seminal papers.

Screening for inclusion

Papers were included if all of the following criteria were met:

- The study participants included children with significant mobility limitations with a known risk for the child's achievement of independent mobility, defined using explicit criteria.
- The intervention described in the paper involved at least one of the five intervention elements defined in *Figure 1* (see also *Chapter 1*, *Background*).
- The outcome (or the 'phenomenon of interest') was related to the child, their family, health or social care, or education.

In applying these criteria, 'mobility limitations' were defined as impairments in the functions of movement and mobility, including functions of joints, bones, reflexes and muscles; control of voluntary and involuntary movements; gait, muscle tone and power; and joint mobility. Conditions for which movement problems were part of the diagnostic criteria or condition definition (e.g. cerebral palsy) were considered to meet the population criterion; judgements about this were made using explicit

rules developed in a previous intervention review in this population (Niina Kolehmainen, Newcastle University, 2018, personal communication) (*Table 2*). No initial age cut-off point was set for 'children' because there is no single agreed cut-off point to use and we wanted to keep the inclusion of evidence broad. Finally, all included papers clearly stated that they either included or did not include children, with no borderline papers present and no specific age cut-off point required.

Papers were excluded if it was not possible to identify outcomes (either measured or described qualitatively), if the intervention was solely non-powered mobility (e.g. manual wheelchair) or if the paper was not based on empirical data (e.g. opinion pieces). The self-initiated prone progression crawler[36] and a powered standing wheelchair[37] were also excluded. Although these could be considered powered mobility interventions in a broad meaning of the word, they were outlier technologies in the scope of the present review. *Figure 3* presents the inclusion/exclusion flow chart.

Although the intention was for the active intervention to be the provision of powered mobility for children aged < 5 years, and for the comparator to be provision for children aged ≥ 5 years, we did not exclude papers on design, comparator or the age of the children in the active intervention at the screening stage, but retained all papers that could broadly inform the review.

Titles and abstracts were screened for inclusion using the software package Rayyan (Qatar Computing Research Institute, Doha, Qatar)[38] by two independent reviewers (LTa, JM or NK), of which at least one was a topic expert. Any discrepancies in decisions about eligibility were discussed until a consensus was reached, including a discussion among the wider team, if necessary. All studies judged to be relevant based on title and abstract were retained and obtained as full texts. EndNote version X8 [Clarivate Analytics (formerly Thomson Reuters), Philadelphia, PA, USA] was used to manage literature.

TABLE 2 Decision rules used to make judgements about population inclusion

Diagnoses and condition groups	Decision	Rationale
• Cerebral palsy • Neuromuscular conditions	Always include in the review	Significant movement problems with known risk to independent mobility are part of the diagnostic criteria or condition definition
• Brain injury (traumatic, acquired) • Developmental co-ordination disorder, dyspraxia, other similar sensory–motor disorders • Global developmental delay, intellectual disability • Hypermobility syndrome • Spinal cord injury • Rare developmental syndromes • Autistic spectrum disorders • Chronic disorders in movement-related body structures (e.g. juvenile idiopathic arthritis)	Included if significant movement problems posing a risk to independent mobility are explicitly mentioned as part of the eligibility criteria or rationale	Although the diagnostic criteria do not necessitate movement problems that are a risk to independent mobility, comorbidity is common
• Attention disorders • Preterm birth, low birthweight • Obesity, respiratory conditions, cancer, enuresis, diabetes, colic, cardiac problems, burns, HIV infection, chronic fatigue syndrome/myalgic encephalomyelitis • Short-term impairments in body structures (e.g. fractures)	Excluded from the review	Movement problems are not inherently part of the diagnostic criteria or condition definition, or are short term

HIV, human immunodeficiency virus.

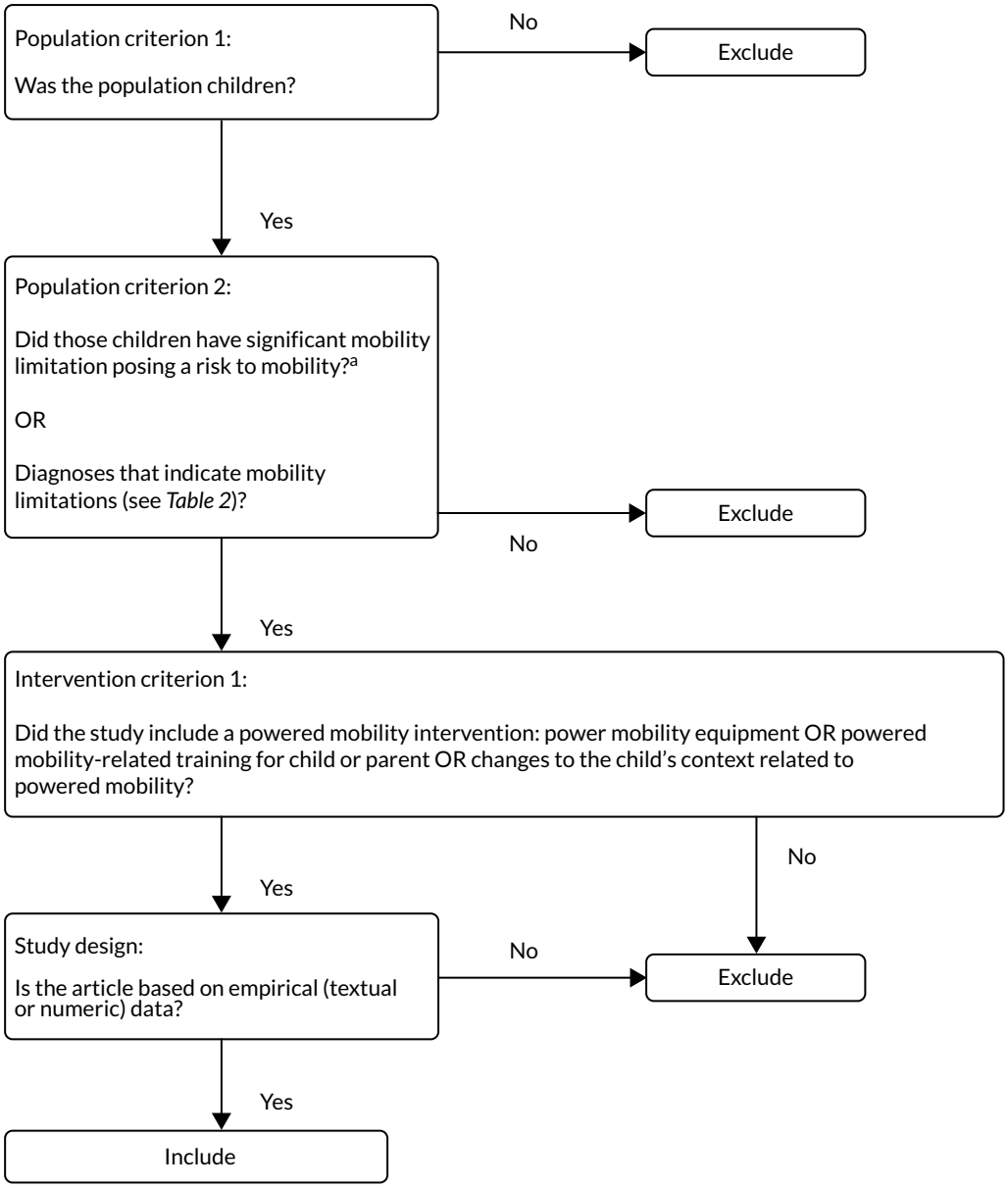

FIGURE 3 Inclusion/exclusion flow chart used during review 1 screening process. a, Mobility is defined as moving by changing body position or location or by transferring from one place to another; carrying, moving or manipulating objects; walking, running or climbing; and using various forms of transportation.

The project advisory group and, in particular, the expert clinicians played a key role in finalising and implementing the inclusion and exclusion criteria, for example by meaningfully defining 'mobility limitations' in very young children; by interpreting papers in which mobility limitations were not explicitly reported; and by checking whether or not the reasons for excluding papers, particularly on the basis of population or outcome, were understandable and acceptable.

Quality appraisal of individual studies

Assessment of the methodological strengths and limitations of included studies focused on risk of bias in RCTs, risk of bias and confounding in non-randomised studies and risks to rigour in qualitative studies. The assessments were used to feed into the development and interpretation of results, and to inform sensitivity and subgroup analyses, but were not used to exclude studies owing to the overall limited quality of the evidence.

The assessment consisted of two stages. First, all included studies were classified in design categories based on their design features (as opposed to primary authors' reported design labels, which are often inconsistently applied).[31] The classification was conducted independently by two reviewers (LTa and JM) using a published algorithm adapted for the purposes of the proposed synthesis,[39–41] with disagreements discussed and arbitration from a third reviewer (NK) as required.

Second, the studies were assessed for methodological strengths and limitations within their classified design categories. All included papers were assessed. The approach to the assessment was that of pragmatism, with focus on obtaining a meaningful and informative picture of the quality of the papers, while also being efficient. A range of tools were used, selected on the basis of the study design category. For RCTs, the established Cochrane Collaboration's tool for assessing risk of bias was used in full, consisting of seven items and options for high, low and unclear risk of bias.[42] For all other quantitative studies, of which the majority were without a comparison group, selected items were used from the Research Triangle Institute (RTI)'s bank of signalling questions for assessing risk of bias, confounding, and precision in non-randomised studies of interventions and exposures.[41] This approach included common items related to sources of threats to validity and precision, including those listed by the Cochrane Collaboration, while allowing them to be used in a way that both differentiated between the studies on quality and was efficient (*Table 3*). In the original protocol, we had anticipated to use the Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) for non-randomised studies;[43] however, using the RTI's bank of signalling questions had a specific advantage in the present review when considering the particular set of included studies. Namely, it facilitated meaningful consideration of confounding which, based on the designs of the included studies, was likely to be a key quality consideration while also being efficient and consistent. This approach required reviewers to learn only one set of items to quality-assess a large number of papers of various designs.

TABLE 3 Selected RTI item bank questions for quality appraisal

Quality appraisal category	Rationale	Proposed RTI items
Detection bias	An important bias category for differentiating the quality of studies; some studies will have considered this more than others	• (Q0)[a] Was attrition/retention reported? • (Q5) Was the assessor blinded to the outcome, exposure or intervention status of the participants? • (Q6) Were valid and reliable measures implemented consistently across all study participants used to assess (6.1) inclusion/exclusion criteria, (6.2) intervention/exposure and (6.3) participant health benefits and harms?
Selection bias	Considering the very small sample sizes and the study designs of the included studies, selection bias was an expected issue for most studies; thus, only key items were required to identify selection bias	• (Q1,2 modified) Are the inclusion/exclusion criteria and recruitment strategy clearly reported? • (Q6) as above
Confounding	Owing to the study designs, confounding was expected to be an issue for most studies, especially the studies without controls/comparisons	• (Q0), (Q2) and (Q6) as above • Q6 (modified) Were valid and reliable measures implemented consistently across all study participants used to assess confounding?[b] • (Q12) Was there any attempt to balance the allocation between the groups or to match groups (e.g. through stratification, matching, propensity scores)?

a Q0 is not from RTI but added here. The RTI has items on how attrition was handled; however, attrition data were limited in the included studies. Thus, this item was used to identify overall issues with attrition/retention reporting.
b The logic model in *Figure 1* presents the full list of potential confounding factors considered relevant to this question.

For qualitative studies, the Critical Appraisal Skills Programme (CASP)[44] qualitative tool was used, as recommended in the Cochrane Qualitative and Implementation Methods Group's guidance.[45] For mixed-method studies, the Mixed Methods Appraisal Tool (MMAT) was used.[46] Grey literature studies were also classified by design, as above, and assessed using the category-appropriate tool. No economic studies were identified and so no tool to quality-assess them was used. Two reviewers (NK and JM) piloted the quality assessment procedures and each included study was independently assessed by two reviewers, with a third reviewer arbitrating disagreements as required to reach consensus and with input from a topic expert. All members of the study were involved in quality assessment.

Data extraction

A bespoke data extraction form was developed based on a previous similar review in this population (Niina Kolehmainen, personal communication), piloted on a small number of included studies and revised as necessary. The following numeric and textual data were extracted from all included papers: the first author; the year of publication; the participants; the country of data collection; verbatim outcome construct/concept(s) targeted or reported by participants (including long-term implications), and any related measure(s); hypothesised change processes ('mechanism', 'process outcomes') and any related measure(s); relevant cost and economic data, and any related measure(s); and evidence about feasibility and acceptability. For intervention characteristics, we had intended to extract the intervention elements using the Template for Intervention Description and Replication (TIDieR);[47] however, owing to reporting limitations in the included studies, this was not possible. We instead used a modified TIDieR-informed template to extract intervention element label(s) verbatim as provided by authors, and key details related to each intervention element. To further inform intervention element descriptions specifically related to very young children, subsets of textual evidence relating to very young powered mobility users were further explored. For these, line-by-line coding was first used to identify data that described any of the intervention elements, and the identified data were then organised thematically. When relevant, the thematic descriptions were further contextualised with visual illustrations (e.g. images of powered mobility equipment or contexts of use).

Throughout, both numeric and textual data were extracted, and the source of the data (e.g. objective measures, participant accounts, author narrative) was recorded. To enable the comparison between the two study groups (children aged < 5 years and children aged ≥ 5 years), both outcomes and intervention data were extracted separately for the two groups when possible.

To extract the data, two independent reviewers (LTa, NK or JM; at least one of whom was a topic expert) read the title, abstract, introduction and methods of the included full texts one at a time; identified the relevant excerpts of text (ranging from a single number or word to strings of numbers and paragraphs) containing information about any of the data aspects above; and copied, verbatim, the extracts from the full texts to a data file. The data extraction was carried out in batches whereby the reviewers independently extracted data for two to five papers and then came together to check consistency. The data extraction process required substantial discussion and interpretation throughout, because of limitations in reporting of the outcomes and related measures, intervention characteristics, and hypothesised change processes.

Mixed-methods framework synthesis of all data

The mixed-methods framework synthesis reviewed and integrated all quantitative, qualitative and mixed-methods evidence to determine the following aims: (aim 1.1) the effectiveness and cost-effectiveness of powered mobility interventions for children with mobility limitations, and the wider impacts to health services and society, and (aim 1.2) the acceptability, feasibility and anticipated outcomes of relevant interventions from multistakeholder perspectives (children, parents, service providers, commissioners, etc.). The included studies provided mainly textual data consisting of brief quotations and original authors' narrative sentences, supplemented with highly heterogeneous numeric data from non-randomised study designs. Most of the studies covered a mix of textual and numeric evidence across health, feasibility, acceptability and implementation outcomes. It was clear at this stage that a lack of statistical analysis,

underpowered studies and poor reporting would hinder the reporting of meaningful numerical and statistical data. Effect sizes, confidence intervals and *p*-values were not typically (or consistently) reported. Most studies appear to be unpowered to detect a significant difference in any outcome. To avoid vote-counting based on *p*-values and giving too much weight to the limited numerical findings,[48] we opted not to present statistical data for the few studies for which such data were available. Rather, we opted to provide an indication as to whether or not the findings suggested an improvement in the outcome measured, without presenting the extent of that improvement.

We used the identification and development of main concepts relevant to the research question as a key thread and structure to the synthesis: we mapped all data (numeric and textual) against these concepts; identified contrasting, complementary and dissimilar data within and across studies, and interrogated these data in relation to the concepts to further shape them and investigate relationships between the concepts; and extended the coverage and expanded the breadth and range of the inquiry by drawing on one type of data to follow up and extend findings from another.[33,49] We followed the commonly used steps of framework synthesis,[34] which mirror the steps of framework analysis.[50]

Familiarisation

During the familiarisation stage, all the researchers in the team immersed themselves in, and developed a sense of, the data available from the included papers by reading through a sample of the included papers. Three researchers (LTa, JM and NK) further took the lead in becoming familiar with the data in-depth by repeatedly reading through and discussing selected papers. Louise Tanner familiarised herself in-depth with all the included papers, Jennifer McAnuff familiarised herself in-depth with the papers that had used quantitative designs and Niina Kolehmainen familiarised herself in-depth with the papers that had used qualitative or mixed-methods designs.

The framework

The logic model (see *Figure 1*) was used as the initial framework and the starting point for organising the data from the included studies. First, textual data from the results sections of the included papers (qualitative, quantitative and mixed methods) were reviewed, compared and contrasted against the concepts in the initial framework. Simultaneously, new issues, codes and themes that emerged from the data were generated and used to shape the concepts, to develop new concepts and to reconfigure the framework. All of the following were considered as data: primary participant quotations, primary author narratives, summary concepts and themes, numbers presented in tables or text, and figures.

Several cycles of concept generation were undertaken; each cycle consisted of the following steps:

- Two initial researchers (LTa and NK) independently read and coded textual data from qualitative and mixed-methods papers.
- The same researchers came together to talk through the emerging issues and themes, and relationships between them.
- The same researchers further agreed key concepts and related content.
- One of the initial researchers (LTa) summarised the agreed concepts and their content in memos.
- That researcher (LTa) then systematically sought for any further, related data from the quantitative and mixed-methods papers, and linked these to the memos.
- The memos were then shared with a third researcher (JM), who independently read them, and critiqued them in relation to the included studies and input from the study expert advisors.
- The three researchers finally jointly discussed, reviewed and further modified the emerging concepts.

Coding of higher-quality papers was prioritised over that of the lower-quality papers, and data on similar outcomes were coded on a single round.

The three researchers who were primarily involved in the synthesis had, between them, expertise in the study population and context, movement and mobility interventions, mixed-methods synthesis, framework synthesis, and quantitative systematic review and synthesis methods. In addition, both the modified and emerging concepts were shared with the wider research team at fortnightly discussions, for independent critique and input. The concepts were also brought to an AniMates workshop for exploration, discussion, interpretation and brainstorming, with outcomes fed back to the study team. At the workshop, concepts were presented as brief statements, and the AniMates members were encouraged to discuss, debate and share their own experiences related to the concepts. AniMates produced artwork and brief animations about the key concepts that they were most interested in, which, in turn, fed back into the research team's thinking about the concepts, and later helped to inform the refined logic model. NVivo version 12 (QSR International, Warrington, UK) and Microsoft Word 2016 (Microsoft Corporation, Redmond, WA, USA) were used to facilitate data management and to maintain a transparent audit trail.

Indexing and charting

Once the key concepts had been agreed, the three researchers (LTa, JM and NK) compared the data of all verbatim outcomes and outcome measures against the key concepts, and 'indexed' the studies to the concepts. The indexing was based on a combination of the verbatim outcomes stated by the primary study authors and the outcome measures used. Each outcome was indexed independently; all indexing was completed by at least two researchers, and all uncertainties taken to a third researcher for further review and discussion.

Once all the outcomes were indexed, and in line with the latest Cochrane recommendations for reviews for which there are no consistent effect measures or data across studies, we used vote-counting tables based on direction of effect to summarise and present the numeric/semiquantitative data in relation to each outcome concept.[48] We explored options for graphical summaries (e.g. harvest plots),[51] but concluded that it was not possible to meaningfully use these, because few studies provided direct, formal evidence about the effectiveness of the intervention. The reasons for the absence of this evidence were various; it was not possible to disentangle these reasons in a manner that supported the construct of harvest plots. For instance, much of the numeric evidence came from studies with a high risk of confounding and/or small sample sizes, or studies with internally conflicting results, making it difficult to place them within the framework that would be used to support harvest plots. In addition, rather than apply one tool to assess bias for all study designs, which is feasible but often lacks sensitivity, we opted to use tools appropriate to study design. This decision introduced an added layer of complexity that would have led to complicated and unclear plots, thus defeating the objective to clearly and succinctly present the findings of the review. Hence, no harvest plots were produced.

Mapping and interpretation

The concepts and the data relating to each concept were shared with the wider research team throughout, and mapped back on to the logic model. In this, the findings from the mixed-methods synthesis were further triangulated and interpreted with the qualitative synthesis findings, and a new framework (in a form of a refined logic model) agreed for evaluating the effectiveness and cost-effectiveness of powered mobility interventions for children (reported in *Integrative synthesis: an integrated logic model to inform the future planning for, and evaluation of, the outcomes of powered mobility for children*). To aid the interpretation, we assessed the support that the evidence provided for each of the identified concepts. In this, we acknowledged the methodological challenges related to grading bodies of evidence in mixed-methods syntheses, while also appreciating the importance of providing some summary indication of the level of support that the evidence from the present review provides for each of the concepts (for a more detailed discussion, see *Appendix 4*). In line with the overall logical methodological stance underpinning the mixed-methods synthesis, we adopted a pragmatic approach to grading whereby we engaged with the broad concept of assessing the certainty of a body of evidence[52] through a practical set of published

mixed-methods-relevant criteria. Specifically, we used the following rating system to provide an overall assessment of the level of support for each concept:

- strong support – converging evidence from a range of designs; no major gaps
- moderate support – converging evidence from a range of designs; clear gaps in data or theory
- low support – converging evidence from a limited pool of designs; clear gaps in data
- very low support – converging evidence primarily from either qualitative or quantitative designs only; substantial gaps in data
- inconsistent support – no converging evidence.

This assessment was also informed by the assessment of a range of mixed-methods-specific criteria (*Table 4*) and supplemented with a criterion for publication bias.

Qualitative thematic synthesis

Our aim in the qualitative thematic synthesis was to focus specifically on the qualitative evidence and further examine the data to create an understanding of how children, young people, parents, siblings and relevant health-care professionals conceptualise, view and experience powered mobility, from which the factors that influence powered mobility preparation, provision, use and outcomes could be explored.

During the qualitative thematic synthesis, we focused on four key contextual areas related to the processes and outcomes of powered mobility: preparation for powered mobility, provision of powered mobility, use of powered mobility and experience of outcomes related to powered mobility. The specific purpose was to see if further theoretical insights could be developed from the qualitative evidence, and to further explore the differences and similarities between powered mobility provision for children aged < 5 years and children aged ≥ 5 years.

All qualitative evidence (from both qualitative and mixed-methods studies) found in the review was synthesised separately for the qualitative thematic synthesis. In defining relevant stakeholder opinions, data from children and young people who used powered mobility were prioritised. Other key

TABLE 4 Criteria considered for concept support in the mixed-methods synthesis

Concept support criteria	Higher degree of confidence about concept, when	Underpinning scientific principles
Truth value/bias	The inferences related to an analytical concept remain sensitive to, and clearly reflective of, the numeric and textual data from the primary studies	Confirmability (qualitative data) and objectivity (quantitative data) Triangulation
Explanation credibility	The analytical concept and the related inferences are theoretically and conceptually sound[a]	Credibility (qualitative data) and validity (quantitative data)
Weakness minimisation	The concept is supported by a range of data (numeric and textual) from different study designs	Triangulation
Inside–outside	The data related to the concept consists of both subjective (insider) views and objective (outsider) observations	Credibility (qualitative data) and validity (quantitative data) Triangulation
Publication bias[b]	There is at least one study that shows non-significant, null, or contrasting results	Representativeness

a We assessed theoretical 'soundness' based on correspondence to similar concepts outside the present study and observable phenomenon that exist independent of the study, as well as the internal coherence and depth of description of the concept.
b This is a different definition of publication bias than used with Grading of Recommendations Assessment, Development and Evaluation (GRADE) and GRADE-CERQual; see *Appendix 4* for further details.

stakeholders included parents, siblings, other family members and professionals involved in powered mobility provision or use (e.g. physiotherapists, occupational therapists, clinicians and teachers).

The Thomas and Harden[53] approach to thematic synthesis was used to identify key descriptive themes and to develop further theoretical insights from the published qualitative findings across the body of evidence. This process was undertaken by three members of the research team (NB, JN and Llinos Haf Spencer). Two researchers (NB and Llinos Haf Spencer) used NVivo to independently code the extracted qualitative evidence, and two researchers (NB and JN) synthesised the evidence. The thematic synthesis approach consisted of three stages:

1. line-by-line coding of all qualitative data in the selected studies, including all participant statements, observations and author interpretations (NB and Llinos Haf Spencer)
2. development of descriptive themes by analysing the relationship between common and complimentary codes (NB, JN and Llinos Haf Spencer)
3. generation of analytical themes through constant comparison and discussion of evidence and further refinement of the descriptive themes (NB and JN).

A separate subgroup synthesis was undertaken for qualitative data relating specifically to children aged < 5 years. For this synthesis, we re-examined all of the coded data relating specifically to very young children and developed descriptive themes. The descriptive themes were contextualised with illustrations to visualise the types of powered mobility equipment used by very young children, to show how these conceptually, physically and technically differ from powered mobility equipment used by older children. We also teased out the nuanced differences in anticipated and experienced outcomes between very young children and older children.

Following completion of the primary and subgroup qualitative thematic syntheses, the GRADE-CERQual approach was used to appraise confidence in all of the synthesised qualitative findings.[35] The process consists of assessing four domains: methodological limitations (i.e. concerns about the design or conduct of studies contributing to each finding), relevance (i.e. the applicability of the context of the studies to the review question), coherence (i.e. clarity of support between the study results and each finding) and adequacy of data (richness and quantity of data supporting each finding). Together, these domains contribute to an overall assessment of confidence in the evidence for each finding.

Results: an overview of evidence of powered mobility interventions for children

The first part of this section reports the results from the search and inclusion process, describes the included studies and summarises the descriptions of the health technology as extracted from the included papers. The subsequent two parts report on the findings from the mixed-methods framework synthesis and the qualitative thematic synthesis, including the grading of certainty. The final part presents the revised, integrated logic model for assessing the effectiveness and cost-effectiveness of powered mobility interventions for children aged < 5 and ≥ 5 years.

Description of the included studies

Number of studies included

The literature searches of bibliographic databases identified 5948 potentially relevant titles and abstracts, of which 221 were included in full-text screening. A further 16 relevant references were identified from reference lists, 30 were identified from the grey literature and 50 were recommended by expert advisors, resulting in a total of 317 references for full-text screening. Of these, 89 references (covering 89 studies) met the inclusion criteria, and 228 references were excluded. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart summarising the study selection process is presented in *Figure 4*.

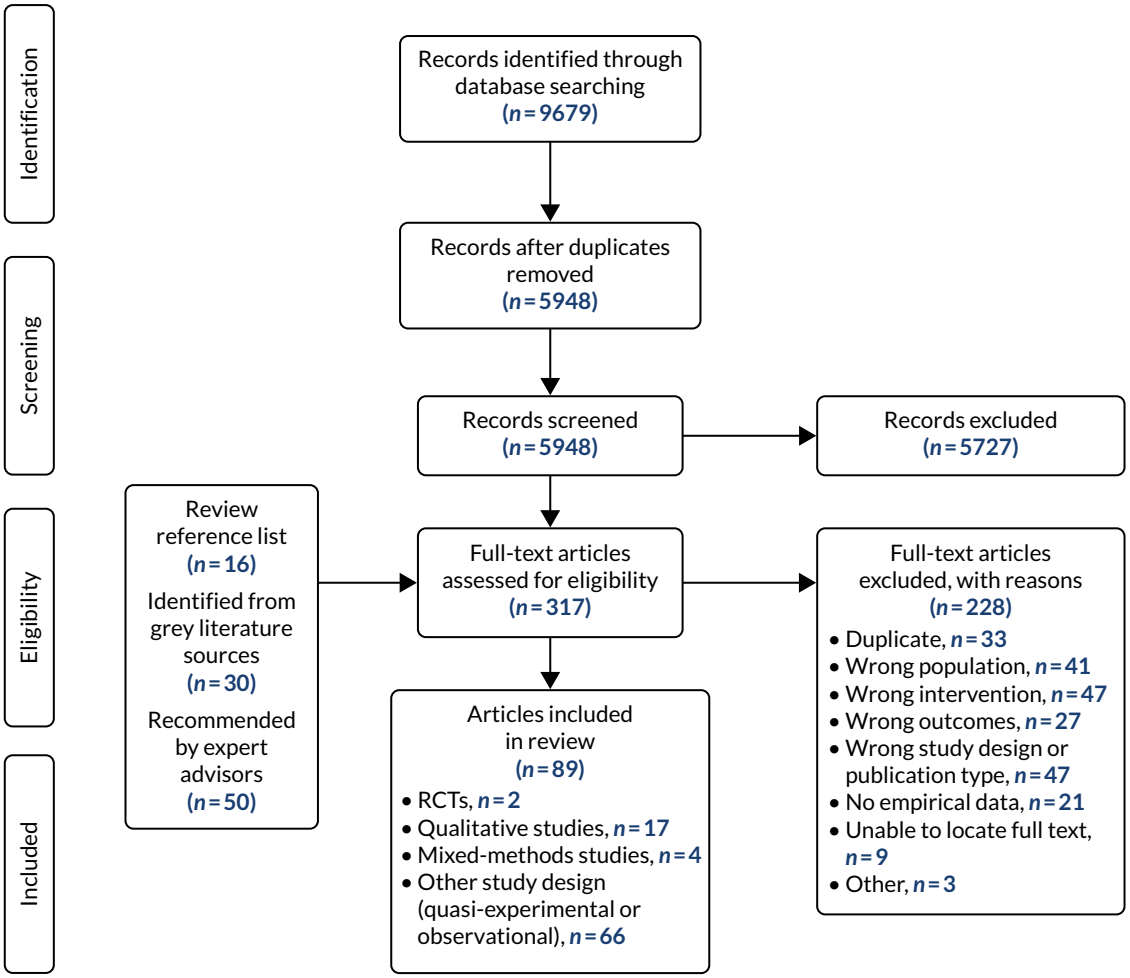

FIGURE 4 The PRISMA flow chart of included and excluded studies.

The list of included studies and associated references is reported in *Appendix 5*. Reasons for exclusion for a sample of excluded studies are described in *Appendix 6*, *Table 40*.

Characteristics of included studies

A full breakdown of included study characteristics is presented in *Appendix 7*, *Table 41*. The included studies comprised two RCTs, 18 qualitative studies, three mixed-methods studies and 66 studies of other designs, such as observational and non-randomised trials. Nearly one-third ($n = 24$) of the studies were single-subject studies, which often consisted of case reports and clinical cases.

The included studies involved an estimated total of 2070 participants. The sample sizes ranged from 1 to 538 participants in individual studies, with a median of five participants. Fourteen studies (16%) had a sample size of ≥ 30 participants, whereas 24 (27%) had only a single participant. One study did not report the number of participants included in the study.[54] The largest study was in children and young people with spina bifida, and reported data for two age groups: children aged 0–15 years ($n = 323$) and young people aged 16–25 years ($n = 215$).[55]

In terms of the reporting of data specifically for the two age groups of interest, 35 (39%) studies reported data for children aged < 5 years, and 25 (28%) reported data on children aged ≥ 5 years. Twenty-one studies (24%) reported data for children across the age groups; of these, 10 (11% of all included studies) reported separate data for children aged < 5 and ≥ 5 years. The age range was unclear in eight (9%) studies.

Most of the included studies ($n = 46$) described multiple diagnoses among the characteristics of their participants. One-quarter ($n = 22$) included solely children with cerebral palsy, three (3%) included solely children with Down syndrome and three (3%) included solely children with spina bifida. About one-third ($n = 28$) of the studies explicitly stated that they included children with learning/intellectual disabilities; however, because of the lack of standardised reporting, there is uncertainty about the actual number of studies.

Included studies were published between 1971 and 2019. Twelve (13%) were published before 2000, and 58 (65%) from 2010 onwards. Studies were conducted in the USA ($n = 46$; 52%), the UK ($n = 11$; 12%), Sweden ($n = 6$; 7%), Taiwan ($n = 4$; 4%), Canada ($n = 5$; 6%), Italy ($n = 3$; 3%), Japan ($n = 3$; 3%), Spain ($n = 2$; 2%) and France, Israel, Australia, Singapore, the Republic of Korea, South Africa, Scotland, Northern Ireland and the Republic of Ireland ($n = 1$; 1% each).

Quality of included studies

Full, agreed quality assessment scores are provided in *Appendix 8*, *Tables 42–45*. For the two RCTs, one study[54] was assessed to have a 'high' risk of bias as a result of bias arising from the randomisation process. The second[14] was assessed as giving rise to 'some concerns' about the risk of bias because of missing data and bias in the measurement of the outcome.

In the case of the 66 observational studies, there were substantial concerns about the lack of control for potential confounding, assessed in relation to the limited extent to which study design features had enabled participant characteristics to be balanced or matched between comparison groups. The quality assessment domains that were rated most positively across the observational studies were for attrition and retention rates.

In the case of the qualitative studies, concerns about the recruitment strategy, relationship between researcher and participant and the clarity of stated findings were most prominent. Among the mixed-methods studies, at least one study (albeit not always the same one) fell short on each quality criterion.

Descriptions of the health technology

Of the included studies, 62 (70%) investigated powered mobility equipment, 20 (22%) investigated powered mobility training and seven (8%) investigated a combination of equipment and training. No studies explicitly set out to investigate the effects, feasibility or implementation related to adaptations to physical environment, policies or practices, or maintenance and review. Further overview on the intervention elements evaluated in the studies is provided in *Appendix 9*, *Table 46*.

Powered mobility equipment

The powered mobility equipment assessed in the included studies clustered around five broad types. A summary of their key features is provided in *Table 5*. The main differences between the types related to the equipment size, appearance and controls. Most, but not all, equipment had been used across age groups, disability populations and settings. We found examples of matching the equipment to a child's development level and desired outcomes, but no single agreed set of principles or prescription criteria emerged.

The qualitative thematic synthesis specifically set out to develop an overview of the different types of powered mobility equipment and their conceptualisation, purposes and uses, which, for simplicity, are reported in the following sections and expanded on in *Table 5*.

Ride-on toys

These interventions are typically battery-operated toys that have been modified for use by a child with a disability. Modifications can include larger wheels, protective bumpers, adapted seating, customised controls, and so on (*Figure 5*). Although these interventions can vary greatly, depending on the specific needs of the child, they are typically used to give children with mobility limitations a chance to play,

TABLE 5 Powered mobility equipment features identified from included studies

Type of powered mobility equipment	Summary description developed from the included studies and expert advisors	Equipment dimensions described to potentially influence uptake, effectiveness and implementation							
		Age range	Conditions/populations used for	Locations of use	Physical comfort and appearance	Tyres, tilt mechanisms	Battery, charging	Control, steering	Size, transportability
Powered wheelchairs, motorised wheelchairs, specialised wheelchair, powered mobility device, EPIOC, SAM system	Full-size powered wheelchairs, and identical scaled-down versions, explicitly designed for use as a mobility aid and tailored for children They offer options for support, specialised seating and control systems, and are usually large and heavy Examples: P110 Quickie (Sunrise Medical Ltd, Dudley, UK); Everard Turbo chair (Everaids Ltd, Bedford, UK) with a Matrix seat	0–81 years	Skeletal dysplasia, above-knee amputations, achondroplasia, arthrogryposis, juvenile rheumatoid arthritis, brain tumour, cerebral palsy, Charcot–Marie–Tooth disease, complete spina bifida without acrania, congenital malformation of limbs, congenital muscular dystrophy, congenital myopathy, Dandy–Walker syndrome, Duchenne muscular dystrophy, failure to thrive, four-extremity limb deficiency, global developmental delay, hydrocephalus, hypoxic brain damage, major postural deficit, multiplex congenita, muscular dystrophy, myelomeningocele, myotonic dystrophy, myotubular myopathy, neurodevelopmental disabilities, neuromuscular disease, orthopaedic disabilities, osteogenesis imperfecta, progeria, quadriplegia of unknown aetiology, rachischisis, spinal muscular atrophy, spina bifida, spinal cord injury, spondyloschisis, stroke, brain tumour, traumatic brain injury, dementia, tetraphocomelia, VATER syndrome	Home, outdoors, laboratory	• Modifications to mount the ventilator and the cylinders so that complete independence of movement was possible • Seating issues included discomfort and inadequate support	Problems with tyres and faulty tilt mechanisms reported by EPIOC users	Problems with batteries reported by EPIOC users	Problems with faulty steering reported by EPIOC users	Size can make it difficult for children to join in, participate and access spaces

Type of powered mobility equipment	Summary description developed from the included studies and expert advisors	Equipment dimensions described to potentially influence uptake, effectiveness and implementation							
		Age range	Conditions/populations used for	Locations of use	Physical comfort and appearance	Tyres, tilt mechanisms	Battery, charging	Control, steering	Size, transportability
Starter powered mobility devices	Powered wheelchair designed specifically for children aged < 5 years, designed to be safe, compact and manoeuvrable, and to be adjusted to accommodate the child's growth up to a limited size/weight Explicitly designed for young disabled children; therefore, it has controls that resemble those on a powered wheelchair, but the actual appearance of the device is child-friendly and more akin to a toy These can be purchased privately, or accessed through loan schemes and certain health services Examples: Wizzybug (Designability, Bath, UK), TinyTrax (TinyTrax, Bristol, UK) and Bugzi (MERU, Epsom, UK)	15–72 months	Cerebral palsy, spinal muscular atrophy, global developmental delay, arthrogryposis, spina bifida	Home and outdoors	Not reported	Not reported	Not reported	Not reported	Size can make it difficult to use device in the home

continued

TABLE 5 Powered mobility equipment features identified from included studies (*continued*)

Type of powered mobility equipment	Summary description developed from the included studies and expert advisors	Equipment dimensions described to potentially influence uptake, effectiveness and implementation							
		Age range	Conditions/populations used for	Locations of use	Physical comfort and appearance	Tyres, tilt mechanisms	Battery, charging	Control, steering	Size, transportability
Smart powered mobility wheelchairs	Standard electric wheelchair chassis to which a computer and a collection of sensors have been added, or a mobile robot base to which a seat has been attached Adaptable to different kinds of wheelchairs (e.g. sports wheelchairs, child wheelchairs, hospital wheelchairs and amphibious wheelchairs) Examples: SMART wheelchairs, (SMART Wheelchairs Ltd, King's Lynn, UK) assisted vehicles, AKKA-board, robotic wheelchair, robotic wheelchair trainer	10 months to 48 years	Various, cerebral palsy, severe mobility limitations and reduced motor control, severely disabled, traumatic brain injury, severe undifferentiated hypotonia, spastic diplegia	Laboratory, home and outdoors	Not reported	Not reported	• Reported options included two 6-V, 9-Ah batteries (offering a reported 4 hours of autonomy) • Reliability on batteries can cause issues	Reported options included switch controls, user board buttons, a controlling system that traces electrical tape on the floor, cameras, range finders, speech synthesisers, bumpers, user interfaces, computer vision, haptic guides and force feedback joysticks	Modifications to the home environment, such as installation of ramps to facilitate access, were reported
Ride-on toys and robots	Children's battery-operated toys, or small robots, specifically modified for the specific needs of an individual child with a disability Modifications can include large wheels, protective bumpers, adapted seating, customised controls Typically used for early movement and active play in early childhood (i.e. < 5 years of age)	6 months to 5 years	Cerebral palsy, complex developmental delays, Down syndrome, 16p11.2 microdeletion, microcephaly, profound and multiple learning disabilities, physical disability, complex medical needs, developmental delay, Pierre Robin sequence, severe undifferentiated hypotonia	• Laboratory, home and outdoors • Can become challenged by rough surfaces; outdoors, can become stuck on grass or on inclines	Limited evidence to suggest that some children may find these devices uncomfortable	Not reported	Reported options included 6-V/single-gear small cars and 12-V/dual-gear large cars	Reported options included joysticks mounted on the toy, or weight shift over a balance board	Most are described as small, relatively lightweight and easily transportable

Type of powered mobility equipment	Summary description developed from the included studies and expert advisors	Equipment dimensions described to potentially influence uptake, effectiveness and implementation							
		Age range	Conditions/populations used for	Locations of use	Physical comfort and appearance	Tyres, tilt mechanisms	Battery, charging	Control, steering	Size, transportability
	The ride-on toys are commercially available, with adaptations accessed through programmes such as GoBabyGo (Cerebral Palsy Foundation, New York, NY, USA). The robots have limited availability, and are generally restricted to research projects Examples: Pioneer (Adept MobileRobots, Amherst, NH, USA), PowerBot (Adept MobileRobots), iRobot Magellan Pro Robot (iRobot Corporation, Bedford, MA, USA), Fisher-Price Mater (Fisher-Price, Inc., East Aurora, NY, USA), PIONEER 3-AT robot (Adept MobileRobots), WeeBot (Adept MobileRobots)								
Powered mobility carts	A seat mounted on a chassis; the seat may be height adjustable. May be specifically constructed for an individual child, and made of various materials Example: the CAPP cart	11 months–14 years	Quadrimembral amputees, multiple limb deficiencies, cerebral palsy, spina bifida, congenital injury of the spine, muscular atrophy, congenital amputations of the arms and legs, cerebral palsy	Laboratory, home and outdoors	Not reported	Not reported	Reported battery options included two 6-V rechargeable gel-cell batteries with 0.5-Ω, 10-W resistor; and a 24-V, 8-Ah lithium ion battery	Reported options included joystick, double-pole, double-throw switch	Removable foam inserts were reportedly used to accommodate child growth over time

CAPP, Child Amputee Prosthetics Project; EPIOC, electrically powered indoor–outdoor chair; MERU, Medical Engineering Resource Unit; SAM, seating and mobility; VATER, vertebrae, anus, trachea, oesophagus and renal.

FIGURE 5 Example of adapted ride-on toy. Reproduced with permission from Julie Laurence (2020, personal communication).

socialise and have active control over their own exploration, which, in turn, is thought to facilitate developmental gains. The devices are not commercially available in their adapted form, but can be accessed through programmes such as GoBabyGo.[56,57] Although these devices are relatively simple, the universality of their toy-based design makes them ideal for introducing powered mobility at an early age.[58]

Starter powered mobility devices

Starter powered mobility devices are explicitly designed for young disabled children, with controls that resemble those on a larger powered wheelchair. A number of different starter powered mobility devices are now available in the UK, including the Wizzybug (Designability, Bath, UK) (*Figure 6*), TinyTrax (TinyTrax, Bristol, UK) and Bugzi (MERU, Epsom, UK). Unlike adapted ride-on toys, starter powered mobility devices are registered medical devices and, although customisable, have standardised designs. Similarly to ride-on toys, these interventions are designed to enable children with mobility limitations to experience and enjoy independent mobility, often for the first time. They may also be used as an introduction to powered mobility and as a wheelchair training tool. They are not routinely used as a child's primary mobility aid, but can be purchased privately or accessed through loan schemes and certain health services. These types of devices are often classed and described as powered wheelchairs, but we believe that they are conceptualised differently to more traditional powered wheelchairs because of their focus on child-centred design.

Powered wheelchairs

Powered wheelchairs for very young children are sometimes scaled-down versions of full-size powered wheelchairs, but can also be specifically designed for children. They are commonly designed to 'grow' with the child, and thus can be adapted to meet each child's needs over time. Therefore, these devices can be used beyond the age of 5 years; weight limit typically defines the upper limit for use, rather than age. They offer more options for support, specialised seating and control systems than starter

FIGURE 6 Example of starter powered mobility device. Reproduced with permission from Designability (Bath, UK).

powered devices, but are usually larger, faster and heavier. Existing models include the Koala Miniflex (Permobil AB, Timrå, Sweden) (*Figure 7*) and Zippie Salsa M2 (Sunrise Medical Ltd, Dudley, UK). These are typically designed for indoor–outdoor use [i.e. electrically powered indoor–outdoor chairs (EPIOCs)], but some models may also be specifically designed for either indoor or outdoor use.

Powered mobility for very young children

There were many similarities in terms of the intervention elements, outcomes and feasibility factors across the age groups, particularly in the prioritisation of autonomy and independence, participation, and social interaction as key outcomes. For example, two studies[59,60] found that parents' primary goals for powered mobility included promotion of independence, autonomy and social inclusion, all of which were noted across studies with older children as well.

Owing to their small sizes and playful, fun designs, ride-on toys[60,61] and starter powered mobility devices[62] were more common among children aged < 5 years, offering a developmentally appropriate and child-centred approach to introducing powered mobility to very young children. Ride-on toys, in particular, offer a relatively inexpensive and fun way to introduce powered mobility and enable movement, participation, social interaction and independence.[58] From the qualitative studies, utilising developmentally appropriate devices and training was found to be important to ensure that children and families are engaged in the process.

Starter powered mobility devices are not typically designed for children aged > 5 years (because of the child's size and weight); thus, powered wheelchairs became the predominant powered mobility intervention found in the older age groups.

FIGURE 7 Example of a powered wheelchair. Reproduced with permission from Permobil AB.

Powered mobility training

Although some of the included studies reported training elements in detail, 9 of the 27 studies (33%) that included training lacked at least some of the basic information, including information about who delivered the training, how many sessions were provided and how long the sessions lasted (*Table 6* presents a summary of the reported training elements). Based on the studies from which information about training was available, the number of sessions ranged from 1 to 64 per participant (estimated median 16 sessions; estimated interquartile range 8–21 sessions), and the session length varied vastly depending on what was described as a session. For example, in one study[67] a 'trial' lasted for 50 seconds, whereas, in another,[74] a session lasted for 30–90 minutes. All studies reported the child as the recipient of the intervention; none reported targeting parents, carers or other people around the child. The training was mainly reported as having been delivered by a researcher and/or a therapy professional, at times with the involvement of parents or carers. Two studies reported using a simulator to deliver the training, and two involved teaching staff in the delivery.

In terms of the nature of the training, the techniques described in the papers mainly targeted a child's skills in driving the powered mobility equipment. From the included papers, five categories of training techniques were identified: (1) graded task, (2) instruction and guidance, (3) feedback, (4) prompts and driving goals and (5) using motivators (*Table 7*). There was evidence of all the techniques being used across the age groups, from as young as 7 months of age. There was also evidence of the delivery of the techniques through virtual reality or computer simulation scenarios for children as young as 3 years of age.

TABLE 6 Reporting of powered mobility training interventions and their key elements

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
[a]Inman *et al.*[54]	Not reported	2 hours per training session	Not reported; the training scenarios were developed by programmers	Children with orthopaedic impairments	• Ability to turn right in actual reality • Ability to turn left in actual reality • Ability to drive down a pavement without going out of bounds in actual reality • Ability to drive up to a wall without hitting it in actual reality
[a]Inman *et al.*[54]	Not reported	2 hours per training session	Not reported; the training scenarios were developed by programmers	Children with cerebral palsy or Down syndrome	• Driving forward at least 25 feet in a straight line within the width of a pavement • Turning 90 degrees to the left • Turning 90 degrees to the right • Driving up to a wall as closely as possible without colliding with it

continued

TABLE 6 Reporting of powered mobility training interventions and their key elements (*continued*)

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Agrawal *et al.*[63]	10 sessions in pilot study 1; 30 sessions in pilot study 2 (follow-up) provided three times per week over a period of 10–12 weeks	• Not reported for pilot study 1 • The follow-up training sessions were each approximately 20 minutes in duration	Not reported; caregivers re-located the robot to different positions during the training	Children with cerebral palsy	• Total path length (m) driven by the children • Success ratio in completing the task (number of successes/number of trials) • Average velocity (m/s) of each task • Hip/knee flexion, roll, sit, kick, walk (GMFM score) • Manual ability to handle objects (MACS score) • Shoulder/elbow/wrist flexion, grasp, weight-bearing (QUEST score) • Self-care, mobility, social function, mobility with caregiver assistance, self-care with caregiver assistance, mobility with caregiver assistance, social function with caregiver assistance (all measured using subdomains of PEDI scores)

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Chen *et al.*[64]	16 sessions in total; four sessions per day conducted over 4 days	The time taken to navigate the training environment varied between trials. The child failed when the travel time reached 600 seconds	The experimenter	Child with spina bifida	To learn navigation and to drive more accurately
Hasdai *et al.*[65]	Total number not reported; frequency was twice a week for up to 12 weeks	30–45 minutes per session	Not reported. Simulator training was used	Children with muscular dystrophy or cerebral palsy	Driving ability and skill involved in operating a powered wheelchair
Lynch *et al.*[66]	Total number not reported; the child participated in training three or four times per week from 7 to 12 months of age	In the Open Exploration period, the infant was allowed up to 20 minutes of unrestricted exploration of the training space	The experimenter and the child's mother	Child with spina bifida	• Number of joystick activations • Path length (m): the average distance that the device travelled with each movement segment in a given session • Total path length (m): the total distance of path length of all movement segments in a given session • Per cent directed driving success: the number of successful trials as a percentage of total trials in one session • Cognition • Language: receptive • Language: expressive • Fine motor skills • Gross motor skills
Marchal-Crespo *et al.*[67]	12 trials: one without guidance, followed by nine with decreasing level of guidance and two more trials without guidance	50 seconds per trial	The experimenters	Child with cerebral palsy	• Steering ability/tracking errors • Driving speed

continued

TABLE 6 Reporting of powered mobility training interventions and their key elements (*continued*)

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
McCourt and Casey[68]	One session	1–1.5 hours per session	Clinical lead occupational therapist	Children with cerebral palsy or Duchenne muscular dystrophy	Ability to safely and competently drive their powered wheelchair outdoors
McGarry *et al.*[69]	16 sessions; two sessions per week for 8 weeks	1 hour per session	The researcher, a fourth-year occupational therapy (honours) student, with guidance from an experienced occupational therapist	Children with cerebral palsy	• Driving skills • Psychosocial outcomes
Morère *et al.*[70]	Maximum of 30 sessions; participants would attend at a rate of two sessions per week	30 minutes per session	Occupational therapist	Children with cerebral palsy	Outdoor driving abilities, including driving behaviour and powered wheelchair control
Torkia *et al.*[71]	One session	The simulator testing and subsequent qualitative interview of each participant lasted 30 minutes	Not reported. Simulator training was used	Children; primary diagnoses included muscular dystrophy ($n = 6$), cerebral palsy ($n = 4$) and a dual diagnosis of spinal cord injury and stroke ($n = 1$)	Children's and adolescents' overall experiences in using the miWe-CC simulator
Ragonesi and Galloway[72]	14 sessions	35–45 minutes per sessions, depending on the infant's mood	The experimenter and one or both parents participated in the training	Child with cerebral palsy	• Independent joystick contacts • Visual attention to joystick • Independent mobility time • Assisted mobility time • Caregiver mobility time • Success in prompted mobility
Nilsson *et al.*[73]	The number of training sessions varied between participants. The data were dichotomised for analysis, grouping participants who received < 30 sessions and those who received > 30 sessions; and grouping participants who received training for < 1 year, 1–2 years and > 2 years	The training duration for each trial in the experiments was generally < 15 minutes	At the start of the project, the researcher was the sole trainer; gradually, other trainers were engaged. These included parents, personal assistants, occupational therapists, physical therapists, teachers, teacher assistants and other staff members in the locations where the training took place	Individuals with profound cognitive disabilities and multivariate additional disabilities, or at high risk of developing such conditions	Success or failure to grow consciousness of joystick use

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Nilsson and Nyberg[74]	42 sessions in total were documented: 20 with one participant and 22 with a second participant. Sessions occurred 1–3 times a week for 4 months	30–90 minutes per session, depending on the child's level of alertness and health at the time	The study author provided the training in the clinic; the children's parents and assistants provided the training at home under supervision from the study author	Two children with profound cognitive disabilities	Children's behaviours during the training; the target behaviours were reactions to the training, unintentional behaviours and intentional activity in the wheelchair
Kenyon *et al.*[75]	Eight sessions; delivered once a week for 8 weeks	45–60 minutes per session	It was reported that the first author, a paediatric clinical specialist, made decisions regarding whether a joystick or switch should be used	Child with cerebral palsy	• Mastery motivation • Spectrum of electroencephalography activity • Daily activities, mobility, social/cognitive function, responsibility • Progress in power mobility use • The mother's perceptions of her child's response to power mobility training
Kenyon *et al.*[76]	21 sessions; delivered twice weekly over a 12-week period (some sessions cancelled by parents because of inclement weather)	60 minutes per session	Not reported	Child with cerebral palsy	• Power mobility skills • Health-related quality of life
Huang and Chen[77]	18 sessions; delivered twice weekly over a 9-week period	The treatment group received 2-hour training sessions using a ride-on car	Occupational therapist	Children with developmental delay, cerebral palsy or Down syndrome	• Mobility • Social function

continued

TABLE 6 Reporting of powered mobility training interventions and their key elements (*continued*)

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Huang *et al.*[78]	18 sessions; delivered twice weekly over a 9-week period	2 hours per session	Occupational therapist	Children with developmental delay, cerebral palsy, Down syndrome, other	• Mobility and socialisation
Huang *et al.*[79,80]	18 sessions; delivered twice weekly over a 9-week period	2 hours per session	Occupational therapist	Children with developmental delay or cerebral palsy	• Self-care • Parenting stress • Treatment duration • Emotional reaction • Family perceptions of the training programme • Effect on play and family interactions • Goal achievement • Mobility • Social function • Mastery motivation • Object persistence • Home affordances
Furumasu *et al.*[81]	Six sessions	1 hour per session	Physical therapist	Children with arthrogryposis, spinal muscular atrophy, spinal cord injury, other (amputee, osteogenesis imperfecta)	• Powered mobility skills
Zeng *et al.*[82]	There was no set number of trials. The number of trials taken to complete the training tests varied between participants. Tests were considered as failed if the subject could not complete the task in 10 trials	Not reported	Not reported	Individuals with traumatic brain injury	• Time to complete a navigation task • Safety (total number of collisions that occurred in a trial) • Joystick movement, which measures the variation of joystick position • Intervention level, which quantifies how often the wheelchair driver needs to modify its command

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Ragonesi *et al.*[83]	One 'training phase'	'Training phase' lasted 10 days	Therapists and teachers	Child with cerebral palsy	• Independent mobility in the classroom • Socialisation in the classroom • Feasibility of providing short-term, supportive 'mobility and socialization' training to increase child's mobility and socialisation in the classroom
[b]Nicholson and Bonsall[84]	Not applicable	Not applicable	Not applicable	Children with cerebral palsy or spinal muscular atrophy	• Number and percentage of powered wheelchairs supplied to children aged < 5 years by the services • Criteria for suitability • Post-provision difficulties with the use of powered wheelchairs • Training opportunities • Waiting times

continued

TABLE 6 Reporting of powered mobility training interventions and their key elements (*continued*)

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Montesano *et al.*[85]	One session	45–60 minutes per session	School-based therapists and engineers	Individuals with cognitive impairment	• Task success: completion of the navigation task • Path length: distance travelled to accomplish the task • Time: time taken to accomplish the task • Collisions: number of collisions during the task • Mean velocity during motion • Usability rate: number of pulsations per mission • Command utility: command usage frequency • Device errors: failures in input detection • Mission success: number of successful missions • Collisions: number of collisions per mission/ distance/period of time • Obstacle clearance: minimum/mean distance to the obstacles • Robustness in narrow spaces: number of narrow passages successfully traversed • Execution, activity and competence analysis

Study	Number of sessions and frequency	Duration of individual sessions	Who the training was delivered by	Who the training was received by	Targeted outcomes
Kenyon *et al.*[86]	10 sessions for two participants, seven sessions for a third participant; delivered once a week over a 12-week period (12 sessions were scheduled for each participant; however, owing to illness and weather-related issues, some sessions were missed)	60 minutes per session	Not reported	Children with cerebral palsy	• Abilities in four domains: daily activities, mobility, social/cognitive, and responsibility • Mastery motivation • Parent goals for power mobility training at the onset of the case; the PMTT was used to identify basic power mobility skills for each participant. Findings were used to create goals for each participant
Logan *et al.*[87]	Between 6 and 64 sessions; delivered over a 12-week period	Session defined as a day when the child drove for at least 20 minutes	Parents and researcher	Children with cerebral palsy, 16p11.2 microdeletion, microcephaly	• Mobility • Visual attention to the switch • Switch contacts • Mobility skills • Days and minutes of driving time • Adherence to recommended use • Parent perceptions of child enjoyment during driving sessions
Logan *et al.*[88]	Total number not reported; sessions delivered daily over a 12-week period	5–40 minutes per session	Family and researcher	Child with Down syndrome	• Mobility • Movement and socialisation • Performance of basic skills and the level of assistance or adaptation required, including self-care, mobility and social function skills • Parent perceptions of child enjoyment, mobility and socialisation

GMFM, Gross Motor Function Measure; MACS, Manual Ability Classification System; miWe-CC, McGill immersive Wheelchair – Community Centre; PEDI, Pediatric Evaluation of Disability Inventory; PMTT, Power Mobility Training Tool; QUEST, Quebec User Evaluation of Satisfaction with assistive Technology.

a Reference reported two separate studies.

b This was a survey about powered mobility; no specific intervention was implemented in the study.

TABLE 7 Five techniques described in the powered mobility skills training programmes

Technique	Summary description of the technique as presented in the studies
Graded task	Modifying the driving environment, the powered mobility or the driving tasks so that the child was achieving success while also challenged to perform with decreasing levels of support or in increasingly demanding situations *The simulation was divided into seven levels of increasing difficulty (. . .)* *Marchal-Crespo* et al.[67]
Instruction and guidance	Verbal instruction and physical (e.g. 'hand-over-hand') guidance for the child and verbal or written instructions for parents *Training included using toys and verbal prompts with hand gestures as well as 'hand-over-hand' assistance to move the joystick (. . .)* *Ragonesi and Galloway*[72]
Feedback	Verbal, haptic and auditory feedback for the child, and natural consequences, including those taking place during self-directed exploration in controlled and/or natural environments *During the entire training program, verbal feedback and natural consequences were used to teach each child that movement and behaviors could have an impact on objects and events in the close vicinity* *Nilsson and Nyberg*[74]
Prompts and driving goals	Using prompts (people, toys, obstacles, etc.) to indicate driving goals, usually consisting of destinations and driving routes *At the start of each trial, he was shown a toy within reaching distance to gain his interest. The experimenter or his mother then moved to the end location and encouraged him to drive* *Lynch* et al.[66]
Using motivators	Using contextual motivators tailored to the child's interest to gain and retain their attention and task-engagement *The participant also appeared to enjoy interactions with the authors, especially the physical therapist student authors, and was often encouraged to 'chase' after a particular student (. . .)* *Kenyon* et al.[76]

Mixed-methods framework synthesis: outcomes, effectiveness and cost-effectiveness

There was no conclusive evidence about the effectiveness or cost-effectiveness of powered mobility in children aged either < 5 or ≥ 5 years. Of the two studies categorised as RCTs, one was a pilot study of early powered mobility provision with 28 children (aged 14–30 months) with various diagnoses.[14] In this study, children in the experimental group received an individually customised powered wheelchair to use for the duration of the study, whereas powered mobility was withheld from the control group for 12 months. The main health outcomes were development [measured using the Battelle Developmental Inventory (BDI)]; mobility, caregiver assistance and self-care [measured using the Pediatric Evaluation of Disability Inventory (PEDI)]; and coping (measured using the Early Coping Inventory); these data were collected at entry and at 12 months. An intention-to-treat analysis showed that the experimental group's BDI receptive communication and total scores, and PEDI mobility skills, caregiver assistance and self-care caregiver scores, improved significantly more than the control group's scores. Although the results provide support for early powered mobility interventions, the small sample size limited the power of the study and it is possible that some of the significant results are spurious. The second study[54] was a multivariate repeated-measures design with 16 children and young people (aged 4–21 years), conducted to evaluate the effect of a virtual skills training programme in a computer-generated world on the real-world powered mobility skills of children with physical disabilities. All who completed the study ($n = 13$) showed gains in real-world driving skills; however, the study was assessed as having a high risk of bias, which limited the certainty of the evidence.

Further analysis and synthesis of all extracted data informed the development of six inter-related outcome concepts that were repeatedly described, across papers, as powered mobility outcomes and areas of impact: (1) movement and mobility; (2) learning to drive powered mobility equipment; (3) participation, play and social interactions; (4) self-care; (5) autonomy, independence, choice and control, and freedom; and (6) psychological consequences (including sense of achievement, confidence, motivation and cognitive outcomes). All of these corresponded with, and further advanced, the outcomes in the initial logic model. Furthermore, two clusters of safety outcomes were identified: (1) emotional consequences (positive and negative feelings for the parent or the child) and (2) accidents and pain. Study data charted onto each identified concept are presented in *Report Supplementary Material 1*.

The following sections report the synthesised numeric and textual data in relation to each of these outcome concepts. For the data that were available, results are presented for both age groups of interest, to enable comparisons. However, overall, across the outcome concepts, we found little evidence to support the hypothesis that the outcomes and impacts of powered mobility were directly related to a child's biological age, and little evidence that a biological age of 5 years provided a significant cut-off point. Instead, we found evidence that each of the six outcome concepts represented a developmental continuum, and that the impact of powered mobility was commonly considered, by a range of stakeholders, in terms of the ways in which it could progress the child's performance further along that continuum. This is further illustrated in the outcome concepts described in detail later and summarised in *Table 8*. Confidence in the findings is discussed at the end of each concept.

Table 8 presents a full list of the papers mapped on to each of the concepts, and a summary of the concepts and their inclusion/exclusion boundaries. *Table 9* presents the powered mobility evidence profile from the mixed-methods synthesis.

Movement and mobility

Movement and mobility was the most frequently described outcome of powered mobility, supported by both the textual and numeric data. Descriptions of movement and mobility related to two related dimensions: (1) play-related movement as an integral part of a movement-based activity (e.g. physical

TABLE 8 Summary descriptions, and the boundaries, of the key concepts identified from the review

The concept (related papers)	Summary description	Included in the concept	Excluded from the concept
Movement and mobility (quantitative studies;[12–14,23,58,62,63,66,75–79,86–92,104,111,112,118,119,123,125,168,169] qualitative studies[61,99–102,105,109,116])	Whole-body movements, usually play-related movement and activity, or destination-focused mobility	• Child-initiated exploration and use of the powered mobility equipment • Movement and mobility in formal and informal everyday situations, including physical activity and play, speed, distance, and actual use of powered mobility • Movement and mobility skills	• The initial learning and acquisition of powered mobility control and skills measured in standardised settings as outcomes of structured powered-mobility training programmes • Other participation outcomes resulting from movement and mobility
Learning to drive the powered mobility equipment (quantitative studies;[13,14,54,58,65–67,69,70,72,75,76,85–88,91–93,106,107,111,113,114,117–119,125,128–130] qualitative studies[61,99,102,117])	The stage or process of the child learning to drive the powered mobility equipment	Learning as an important stage or process, separate from the everyday, actual, real-life use. Focuses on acquisition of skills and abilities in a controlled environment or in a formal training context	Movement and mobility in everyday life, fit and physical environment

continued

TABLE 8 Summary descriptions, and the boundaries, of the key concepts identified from the review (*continued*)

The concept (related papers)	Summary description	Included in the concept	Excluded from the concept
Participation, play and social interactions (quantitative studies;[12–15,17,23,58,62,63,75,77–79,83,86,88–98] qualitative studies[59–61,99–103])	Children living their everyday lives across activities and contexts	• Children's involvement in everyday activities, engagement in life situations and social interactions, exploration and play, friends, and pushing the boundaries of what the children did in everyday life • The social and play skills needed for participation	• Movement, mobility and learning to use powered mobility • Cognitive and attentional skills • Movement and mobility skills
Self-care (quantitative studies;[13,17,58,63,86,88,104] qualitative studies[60,100,105])	Looking after oneself and directing/making decisions about one's self-care	• Ability to undertake basic tasks related to looking after oneself, such as eating or drinking • Caregiver assistance	• Autonomy, freedom, choice and control • Participation
Autonomy, independence, choice and control, and freedom (quantitative studies;[12,13,58,62,75,76,86,89,91–93,98,106–108] qualitative studies[59–61,99–103,105,109,110])	Higher-level values and aspired states related to autonomy, independence, choice and control, and freedom	• The broader states of 'being' autonomous, free and independent, and having choice, control and freedom • Challenging/defying rules and social conventions • Self-initiation and control	• Specific, observable everyday examples and manifestations of freedom and autonomy, which have been coded separately under participation, movement, mobility and self-care • Any component skills
Psychological outcomes (quantitative studies;[14,23,58,66,75,76,79,80,86,91–93,95,106,111–115,] qualitative studies[60,61,101,116,117])	Sense of achievement and motivation	• Achievement, belief in ability, competence, confidence, motivation, success, self-efficacy, beliefs about capabilities • The child or the parent perception	Objective measured skills, ability and observable competence
	Cognitive outcomes	Basic cognitive language and communication skills	Social participation, relationships, interactions and friendships
Safety outcomes (quantitative studies;[12,15,17,23,76,77,79,82,87,88,91,98,106,112,115,118–121,] qualitative studies[59–61,74,99–103,109])	Emotional consequences	The child's and their parents' emotions and feelings related to powered mobility	Accidents, physical pain, road safety
	Accidents and pain	Accidents, pain, road safety, traffic, physical discomfort	Any harm that took place during formal training (coded under learning)

play and games) or as an end point itself (e.g. the sensation of spinning) and (2) destination-focused mobility, whereby movement is a means of transfer to a place or a situation.

Play-related movement: selected quotations demonstrating the concept

> *After a short period of driving in circles after release of guidance, she gave a small smile and later still she laughed with delight. Apparently she enjoyed the activity without being aware of what caused the motion of the chair.*
>
> *Researcher, Nilsson and Nyberg*[74]

TABLE 9 Powered mobility evidence profile from the mixed-methods synthesis

The outcome concept	Number of studies per design	Combined sample size (*n*)	Importance of the outcome to children and families as extracted from data	Evidence supporting concept
Movement and mobility	• RCT = 1 • Observational = 26 • Qualitative = 6 • Mixed methods = 1	812	Critical	Strong
Learning to drive powered mobility	• RCT = 2 • Observational = 36 • Qualitative = 4 • Mixed methods = 1	454[a]	Low	Inconsistent
Participation, play and social interactions	• RCT = 1 • Observational = 23 • Qualitative = 8 • Mixed methods = 1	469	Critical	Moderate
Self-care	• Observational = 5 • Qualitative = 2	41	Insufficient evidence	Low
Autonomy, independence, choice and control, and freedom	• Observational = 13 • Qualitative = 10 • Mixed methods = 1	362	Important, but not critical	Low
Sense of achievement, confidence and motivation	• Observational = 7 • Qualitative = 2	728	Insufficient evidence	Low
Cognitive outcomes	• RCT = 1 • Observational = 15 • Qualitative = 3	673	Insufficient evidence	Low
Positive and negative feelings	• Observational = 16 • Qualitative = 10	366	Important, but not critical	Low
Accidents and pain	• Observational = 2 • Qualitative = 2	397	Critical	Low

a Number of participants not reported for one observational study (i.e. Inman *et al.*[54]).

He played baseball this year, so he was able to run the bases in his power chair, which he could never have done beforehand.

Parent, Wiart et al.[102]

Enjoying movement for its own sake was also important, particularly for some of the boys who both described and demonstrated their enjoyment of the sensation of movement and speed.

Researcher, Gudgeon and Kirk[99]

Destination-focused mobility: selected quotations demonstrating the concept

I don't have to like wait for them and I can get there at my own speed.

Child, Gudgeon and Kirk[99]

(. . .) he can now go with the others and see what the other people are doing.

Parent, Sonday and Gretschel[101]

It is this idea that you have one method of walking or moving whereas actually in reality all of us use a different method of moving around and even able bodied children they have (bikes, cars, skateboards. . .).

Professional (clinicians, wheelchair prescribers), Durkin[109]

One or both of these dimensions of movement and mobility were commonly the primary outcome(s) of powered mobility. Movement and mobility was consistently the first point in the causal chain of hypothesised health outcomes: a key gateway to other health outcomes such as participation, autonomy and freedom, and the stated mechanism that linked these other outcomes to powered mobility. Descriptions of movement and mobility were present in the voices across children, parents, professionals and researchers, as illustrated in the preceding quotations.

We explored both the textual and numeric data for differences in movement and mobility related to age. In textual data, play-related movement was described as a key outcome for all children, from the very youngest powered mobility users[101] to teenagers.[59,100,102] Destination-focused mobility appeared to be mediated by a range of factors, including a child's developmental level and the situational feasibility, with little evidence of a child's biological age being a directly contributing factor. In the numeric data, most studies indicated that powered mobility had positive effects on children in both age groups (*Table 10*).

In studies of very young children, the most common measure to capture movement and mobility outcomes was the PEDI, especially its mobility scale, which showed improvement in all studies but one (see *Table 10*). Four studies[23,63,66,92] used measures of movement-related skills (e.g. Bayley Scales of Infant Development, Gross Motor Function Measure-88 items), two of which showed improvement. In studies of children aged ≥ 5 years, no two studies used the same measure and none used the PEDI. See *Table 10* for verbatim outcomes mapped to the 'mobility and movement' concept.

The assessment of certainty for the concept indicated strong support for movement and mobility as a powered mobility outcome (*Table 11*); this was across the younger and older children, with evidence from both controlled and real-world settings. As for the overall review, there was no formal evidence of effectiveness, but the cumulative support across designs was strong. There was no evidence to make any judgements on cost-effectiveness.

Learning to drive the powered mobility equipment

In a chain of powered mobility outcomes, movement and mobility were often implied to emerge after an initial process of learning to acquire the ability to drive powered mobility. Often, although not always, this was learning in a controlled environment before everyday use. The form of the learning process was described differently in different papers, depending on the trainer's or researcher's approach to learning. Some studies emphasised emerging skill acquisition through self-directed use (especially those using self-directed exploration; see *Powered mobility training*), whereas others focused on structured development of skills. Several papers also explicitly drew on both approaches as ways to achieve learning:

> *Learning to use powered mobility was viewed by all participants as an individualized, cyclical process that occurred over time.*
>
> *Researcher, Kenyon* et al.[61]

> *A lot of children when they first learn to move . . . first need to learn to move and what it is about to move and explore and then driving is much later (. . .).*
>
> *Professional, Durkin*[109]

The descriptions of the learning process and everyday use could not necessarily be separated from one another by how the activity looked from outside. This was especially true of exploratory play, which was described as both learning and play-related everyday use. Which of these it was viewed to be depended on the purpose of the activity as intended by adults, the child's developmental stage, the child's powered mobility competence and preference, and the trainer's approach to skill acquisition. Although it was common for powered mobility professionals and researchers to conceptualise the

TABLE 10 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'mobility and movement' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'movement and mobility'	No change in 'movement and mobility'	Negative change in 'movement and mobility'		
Study population aged < 5 years	• Frequency of self-initiated changes of location in space (target behaviours were coded from video recordings) (Butler;[89] *n* = 6) • Mobility (PEDI mobility subscale), family perceptions of the training programme (parent descriptions) (Huang *et al.*;[79] *n* = 29) • Mobility (mean weekly driving performance) (Huang *et al.*;[78] *n* = 10) • Mobility (PEDI mobility subscale) (Huang and Chen;[77] *n* = 20) • Mobility (video observations and PEDI mobility subscale) (Huang *et al.*;[17] *n* = 1) • Mobility (PEDI mobility subscale) (Jones *et al.*;[13] *n* = 1) • Mobility (PEDI mobility subscale) (Jones *et al.*;[14] *n* = 28) • Mobility (PEDI mobility subscale) (Huang *et al.*;[75] *n* = 1) • Mobility (PEDI mobility subscale) (Kenyon *et al.*;[86] *n* = 3) • Mobility (video observations), mobility skills (PEDI mobility and caregiver assistance subscales) (Logan *et al.*;[87] *n* = 3) • Mobility (percentage of time and total time that child spent in independent or assisted mobility, PEDI mobility subscale), parent perceptions of child's mobility (daily activity log, questionnaire) (Logan *et al.*;[88] *n* = 1) • Development in motor, cognitive, language and social skill domains (PEDI, BSID) (Stokes *et al.*;[92] *n* = 1)	Gross motor skills (BSID) (Lynch *et al.*;[66] *n* = 1) Motor skills (BDI fine and gross motor skills subscales, Merrill Palmer Revised fine and gross motor subscales), mobility (PEDI mobility subscale) (Mockler *et al.*;[111] *n* = 31) Hip/knee flexion, roll, sit, kick, walk (GMFM-88) (Agrawal *et al.*;[63] *n* = 15) Mobility (PEDI mobility subscale), developmental skills (BDI motor subscale) (Jones *et al.*;[14] *n* = 28)	N/A	77 (16)	++

continued

TABLE 10 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'mobility and movement' concept (*continued*)

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'movement and mobility'	**No change in 'movement and mobility'**	**Negative change in 'movement and mobility'**		
	• Mobility (PEDI mobility subscale), mobility with caregiver assistance (PEDI caregiver assistance subscale) (Agrawal *et al.*;[63] $n = 15$) • Range of independent locomotion, motor skills (questionnaire) (Uyama and Hanki;[112] $n = 318$) • Upright independent locomotion (descriptive, textual data), (Flodin;[122] $n = 1$) • Independent mobility in the classroom (not reported) (Ragonesi *et al.*;[96] $n = 1$)				
Study population aged ≥ 5 years	• Self-initiated movement (counts of self-initiated movement with no physical assistance determined by video recordings) (Deitz *et al.*;[12] $n = 2$) • Health-related quality of life (CPCHILD) (Kenyon *et al.*;[76] $n = 1$) • Walking endurance (2MWT), walking speed (10MWT) (Smania *et al.*;[123] $n = 1$) • Mobility (WeeFIM locomotion score) (Kornafel *et al.*;[104] $n = 1$)	N/A	N/A	100 (4)	++

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'movement and mobility'	No change in 'movement and mobility'	Negative change in 'movement and mobility'		
Study population aged under and over 5 years	• Motor activities (observational data scale) (Guerette *et al.*;[124] *n* = 23) • Achievement of goals related to development of mobility skills (parent ratings of whether goals were fully, partly or not achieved) (Evans and Baines;[62] *n* = 90) • Motor development (evaluation by physiotherapists) (Paulsson and Christoffersen;[95] *n* = 12) • Exploration (percentage of time driving independently, assisted or caregiver-driven) (Logan *et al.*;[118] *n* = 3) • Mobility (textual data, video observation) (Odor and Watson;[91] *n* = 13) • Mobility (5-point scale), postural ability (Chailey Heritage levels of sitting ability) (Pope *et al.*;[125] *n* = 9)	Gross motor activities (GMFM) (Bottos *et al.*;[23] *n* = 29)	N/A	83.3 (6)	++

10MWT, 10-Minute Walk Test; 2MWT, Two-Minute Walk Test; BSID, Bayley Scales of Infant Development; CPCHILD, Caregiver Priorities and Child Health Index of Life with Disabilities; GMFM, Gross Motor Function Measure; GMFM-88, Gross Motor Function Measure-88 items; N/A, not applicable; WeeFIM, Functional Independence Measure for children.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, the summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 11 Support for the concept of 'movement and mobility' as an outcome of a powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	Clear evidence reflected in both numeric and textual data	Strong
Explanation credibility	Movement and mobility are established concepts, and efficacy of powered mobility on child's movement and mobility is directly observable and evidenced in the primary studies. The studies further show feasibility and acceptability of implementation across age range, making this a theoretically sound effectiveness outcome	Strong
Weakness minimisation	Supported across different designs (RCTs, observational, qualitative, mixed methods)	Strong
Inside–outside	The data cover child, parent, professional and researcher views, and objectively recorded (e.g. video) observations	Strong
Publication bias	There are studies that show non-significant results, especially in relation to movement skills (which is theoretically consistent with the intervention hypotheses in this population)	Strong
Additional comments	No formal evidence of effectiveness, but the overall cumulative evidence is strong. No evidence to make any judgements on cost-effectiveness	N/A

N/A, not applicable.

initial learning process as a discrete stage, children themselves described continued learning as part of their everyday use of the equipment:

> *If you crash it tells you how much room you need – how much careful you have to be because it is not that big or it is big.*
>
> *Child, Durkin*[109]

In terms of differences in learning outcomes by age, there were no differences in the included studies. There was some suggestion that structured learning, targeted through specific techniques, may be particularly important for children with significant cognitive impairments.[74,117] These same papers also demonstrated that it was feasible for children with profound cognitive impairments with added visual impairments and very limited body movements to learn to use powered mobility. All included studies that reported on learning outcomes described positive results, with one study also noting negative results (*Table 12*).[72] Therefore, there was no scope for assessing the efficacy of specific approaches to supporting children to use powered mobility.

The assessment of certainty for the concept indicated inconsistent support for learning to drive powered mobility as a powered mobility intervention outcome (*Table 13*). A large number of included papers had investigated this outcome, including studies of different designs (although there was no formal evidence of effectiveness). The inconsistent overall rating stemmed largely from the two views of the place of learning in the powered mobility intervention causal chain, and the inconsistent operationalisation of the concept as a possible outcome.

Participation, play and social interactions

Participation, play and social interactions formed a prominent cluster of interlinked outcomes in both the textual and numeric data. These outcomes were described as consequences of powered mobility-enabled movement and mobility. Their core focus was children living everyday lives across contexts, including engagement with friends and social interactions, exploration and play, physical activity, and pushing the boundaries of what the children could do and were allowed to do.

TABLE 12 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'learning process' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'learning process'	No change in 'learning process'	Negative change in 'learning process'		
Study population aged < 5 years	• Competent control of a motorised wheelchair (achievement of seven driving skills developed by the study investigators) (Butler *et al.*;[126] *n* = 13) • Deviation from the desired path (deviation area, measured using m^2) (Chen *et al.*;[64] *n* = 1) • Control of a powered wheelchair (clinical observations made by the study author) (Douglas and Ryan;[115] *n* = 1) • Independent mobility (Power Mobility Skills Checklist) (Dunaway *et al.*;[127] *n* = 6) • Functional performance with a powered wheelchair (Powered Mobility Programme) (Furumasu;[81] *n* = 24) • Self-generated mobility (on-board computer measuring total session time, percentage of session time spent driving and total path length) (Galloway *et al.*;[57] *n* = 1) • Child development (BDI) (Jones *et al.*;[13] *n* = 1) • Competence in manoeuvring the power wheelchair (Wheelchair Skills Checklist) (Jones *et al.*;[14] *n* = 28) • Occupational performance (COPM), progress in power mobility use (Assessment of Learning Powered mobility use; Wheelchair Skills Checklist) (Kenyon *et al.*;[75] *n* = 1) • Desired parental outcomes for power mobility training (achieved/not achieved, reported by parents) (Kenyon *et al.*;[86] *n* = 3) • Visual attention to the switch and switch contact (coding of video-recording of car play sessions) (Logan *et al.*;[87] *n* = 3) • Mobility (daily activity log completed by parents and a questionnaire of their perceptions of mobility at each phase of the study) (Logan *et al.*;[88] *n* = 1)	N/A	Increased caregiver mobility time (coding of video footage) (Ragonesi and Galloway;[72] *n* = 1)	100 (23)	++/–

continued

TABLE 12 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'learning process' concept (*continued*)

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'learning process'	No change in 'learning process'	Negative change in 'learning process'		
	• Behaviour in response to discrimination cue (on-board monitoring device), vocalisations and smiles (recording of participant behaviour throughout the experiment) (Lovett[113] $n = 4$) • Driving ability (on-board monitoring device and video-coding) (Lynch *et al.*;[66] $n = 1$) • Power mobility proficiency (Powered Mobility Program, Wheelchair Skills Checklist) (Mockler *et al.*;[111] $n = 31$) • Independent joystick contacts, visual attention to the joystick, independent mobility time, assisted mobility time (coding of video footage) (Ragonesi and Galloway;[72] $n = 1$) • Driving skills (driving time to complete a maze) (Schoepflin *et al.*;[128] $n = 1$) • Prompted and independent mobility (analysis of behaviour in videotaped sessions) (Stokes *et al.*;[92] $n = 1$) • Hand function to use switches to operate the powered mobility (clinical determination by a physical therapist) (Weinstein *et al.*;[93] $n = 1$) • Independent mobility (case descriptions) (Zazula and Foulds;[119] $n = 1$) • Driving performance and goal-directed movement (coding of videotaped free-play sessions) (Larin *et al.*;[129] $n = 3$) • Exploration and enjoyment (coding of videotaped free-play sessions) (Logan *et al.*;[118] $n = 3$) • Infant independent activation when using the car in seated and standing modes (lack of information regarding the data collection tools) (Logan *et al.*;[87] $n = 4$)				

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'learning process'	No change in 'learning process'	Negative change in 'learning process'		
Study population aged ≥ 5 years	• Driving ability (Functional Evaluation Rating Scale and simulation program) (Hasdai *et al.*;[65] *n* = 22) • Number of collisions (Furumasu's tasks for driving readiness); independent mobility (no measure specified) (Huhn *et al.*;[130] *n* = 1) • Power mobility skills (number of switch activations) (Kenyon *et al.*;[76] *n* = 1) • Steering ability/tracking errors, driving speed (no measure specified) (Marchal-Crespo *et al.*;[67] *n* = 1) • Safe and competent driving (EPIOC score sheet) (McCourt and Casey;[68] *n* = 3) • Task success – completion of navigation task (on-board monitoring device) (Montesano *et al.*;[85] *n* = 4) • Mobility support (descriptive) (Omori *et al.*;[114] *n* = 2) • Outdoor driving abilities (WST-F evaluation grid) (Morère *et al.*;[70] *n* = 12)	Time to complete a navigation task (on-board monitoring device) (Zeng *et al.*;[82] *n* = 1 under 18 years)	N/A	88.9 (9)	++
Study population aged < and ≥ 5 years	• Driving competence (Furumasu's driving test) (Bottos *et al.*;[23] *n* = 29) • Increase in autonomy level when driving the vehicle (driving levels 1–5) (Ceres *et al.*;[120] *n* = 5) • Length of time to use the powered wheelchair independently indoors/outdoors, skills necessary to operate the prototype, number of switch and joystick inputs by the child, skills in operating the prototype, duration of each test (survey questions answered by families of child recipients of powered mobility) (Kakimoto *et al.*;[107] *n* = 2) • Driving skills (Powered Mobility Program, adapted) (McGarry *et al.*;[69] *n* = 4)	N/A	N/A	100 (9)	++

continued

TABLE 12 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'learning process' concept (*continued*)

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'learning process'	**No change in 'learning process'**	**Negative change in 'learning process'**		
	• The ability to turn right in actual reality, ability to turn left in actual reality, ability to drive down a pavement without going out of bounds in actual reality, ability to drive up to a wall without hitting it in actual reality (on-board monitoring device), (Inman *et al.*;[54] *n* = not reported) • Driving skills (wheelchair driving skills evaluation protocol) (Inman *et al.*;[54] *n* = 13) • Goal-directed behaviours, time in motion and infant's driving performance (successful completion of driving performance trials) (Larin *et al.*;[129] *n* = 3) • Exploration and enjoyment (% of time driving independently/assisted/caregiver-driven; % and frequency count of positive/negative facial expressions) (Logan *et al.*;[118] *n* = 3) • Success or failure to grow consciousness of joystick use (assessment tool in the eight-phase learning process) (Nilsson *et al.*;[73] *n* = 45) • Safety (textual data, video-coding) (Odor and Watson;[91] *n* = 13)				

COPM, Canadian Occupational Performance Measure; N/A, not applicable; WST-F, Wheelchair Skills Test Form.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 13 Support for the concept of learning to drive powered mobility as an outcome of powered mobility training

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept has unclear boundaries, with key elements of the concept described differently in different studies. All aspects of the concept could not be clearly reflected through numeric and textual data from the primary studies	Inconsistent
Explanation credibility	The concept of learning skills, or developing an ability to do something, is well established. In the included body of evidence, there was an inconsistent view over the hypothesised role of learning in powered mobility use, and about how central it was as an initial outcome. Some viewed learning as a necessary stage before everyday adoption, whereas others viewed everyday adoption as the most effective way to learn. The elements of powered mobility interventions (primarily the training) proposed to produce the learning outcome were poorly specified on key features	Inconsistent
Weakness minimisation	The concept is supported by a range of numeric and textual data from different study designs (RCTs, observational, qualitative, mixed methods)	Strong
Inside–outside	The accounts and views between children (insiders) and others (outsiders) diverged, with children viewing learning as ongoing, whereas others (especially professionals) tended to view it as a stage	Inconsistent
Publication bias	There is at least one study that reports contrasting results	Strong
Additional comments	None	N/A

N/A, not applicable.

In the textual data, descriptions of these outcomes were present in the voices across children, parents, professionals and researchers:

> *I can go shopping (. . .) I can play basketball at my Saturday club all by myself.*
>
> *Child, Sharma and Morrison*[98]

> *If she didn't have the power chair then she'd have to rely on the teacher aide and then the teacher aide's with her constantly. So that kind of interferes with socialization.*
>
> *Parent (mother), Wiart* et al.[102]

> *(. . .) powered mobility brought major changes in play that was marked by an increase in active play (. . .)*
>
> *Researcher, Sonday and Gretschel*[101]

> *She plays hide and seek or sometimes the children runs and she tries to catch them or they sometimes hop onto the back and she gives them a drive.*
>
> *Parent, Sonday and Gretschel*[101]

> *[powered mobility allowed] participation in age-appropriate activities within their peer group such as playing in the school's sports team, shopping, or going out with friends.*
>
> *Professionals, Pituch* et al.[100]

> *(. . .) the importance of participation and how each child's mobility technology mediated participation, daily activity and interaction with siblings, peers and adults.*
>
> *Researcher, Feldner* et al.[60]

In the numeric data, most studies indicated that powered mobility had a positive impact on some of the component skills related to play and social interactions, especially social function (*Table 14*). There were limited data on the wider concepts of actual everyday participation, play and friendships.

TABLE 14 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'participation, play and social interactions' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'participation, play, social interactions'	No change in 'participation, play, social interactions'	Negative change in 'participation, play, social interactions'		
Study population aged < 5 years	• Frequency of self-initiated communications with caregiver (target behaviours were coded from the video-recordings) (Butler;[89] $n = 6$) • Social function (PEDI social function subscale) (Huang and Chen;[77] $n = 20$) • Social function (PEDI social function subscale), family perceptions of the training programme (weekly activity log, recorded by parents; mainly qualitative data that involved parent descriptions) (Huang *et al.*;[79] $n = 29$) • Social function (PEDI social function subscale), socialisation (number of times child reached for toy/adult, number of positive facial expressions, number of times child vocalised), spontaneous family interaction (duration, in minutes, that family spontaneously interacted with child during 10-minute car play) (Huang *et al.*;[17] $n = 1$) • Social function (PEDI social function subscale) (Jones *et al.*;[13] $n = 1$) • Social/cognitive scaled score (PEDI-CAT social/cognitive subscale) (Kenyon *et al.*;[86] $n = 3$) • Social function (PEDI social function subscale), parent perceptions of child socialisation (daily activity log and questionnaire) (Logan *et al.*;[88] $n = 1$) • Socialisation in the classroom (amount of time child spent interacting with peers and teachers) (Ragonesi *et al.*;[96] $n = 1$) • Socialisation in the classroom (amount of time spent solitary, in parallel play, in teacher interaction, in peer interaction) (Ragonesi *et al.*;[83] $n = 1$)	• Socialisation (mean number of times each week for all participants for positive facial expressions, child-initiated contacts and initiation of contact by others) (Huang *et al.*;[78] $n = 10$) • Social function (PEDI social function subscale, BDI personal social subscale) (Jones *et al.*;[14] $n = 28$) • Social/cognitive scaled score (PEDI-CAT social/cognitive subscale) (Kenyon *et al.*;[86] $n = 3$) • Play behaviours (video-recordings with data classified using Howes' Peer Play Scale) (Ross *et al.*;[97] $n = 5$)	N/A	77.8 (14)	++

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'participation, play, social interactions'	**No change in 'participation, play, social interactions'**	**Negative change in 'participation, play, social interactions'**		
	• Social function (PEDI social function subscale), social function with caregiver assistance (PEDI social function with caregiver assistance subscale) (Agrawal *et al.*;[63] $n = 15$) • Social behaviour, vocalisations (Bayley III developmental assessment, and amount of time engaged in vocalising and social behaviour) (Dennis *et al.*;[94] $n = 2$) • Play behaviours (Howes' Peer Play Scale) (Logan *et al.*;[90] $n = 1$) • Development in motor, cognitive, language, and social skill domains (BSID, PEDI) (Stokes *et al.*;[92] $n = 1$) • Social skills (measure not reported) (Weinstein *et al.*;[93] $n = 1$)				
Study population aged ≥ 5 years	• Child initiations directed to adults and peers, adult and peer initiations directed to child (number of observation intervals in which contacts with others were recorded) (Deitz *et al.*;[12] $n = 2$)	N/A	N/A	100 (1)	+

continued

TABLE 14 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'participation, play and social interactions' concept (*continued*)

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'participation, play, social interactions'	No change in 'participation, play, social interactions'	Negative change in 'participation, play, social interactions'		
Study population aged < and ≥ 5 years	• Activities of daily living (COPM), social participation (Impact of Childhood Illness Scale) (Bottos *et al.*;[23] *n* = 29) • Achievement of goals related to social inclusion and play (parent ratings of whether goals were fully, partly, or not achieved) (Evans and Baines;[62] *n* = 90) • Effects of having a powered wheelchair as perceived by parents (questionnaire and 5-point scale) (Home and Ham;[106] *n* = 57) • Psychosocial (social, emotional) development (parent report) (Paulsson and Christoffersen;[95] *n* = 12) • Social development, communication (textual data, response to questions) (Odor and Watson;[91] *n* = 13)	N/A	N/A	100 (5)	++

BSID, Bayley Scales of Infant Development; COPM, Canadian Occupational Performance Measure; N/A, not applicable; PEDI-CAT, Pediatric Evaluation of Disability Inventory – Computer Adaptive Test.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when studies suggested inconsistent results, the summary code was ??.

We explored, but found little to suggest, substantial variation by age. Although the nature of the activities the children engaged in varied, this variation appeared to be related to their developmental level, powered mobility competence, and environmental factors, rather than biological age.

The assessment of certainty for the concept indicated overall moderate support for participation, play and social interactions as a powered mobility intervention outcome (*Table 15*). The concept was theoretically sound, including the hypothesised mechanisms linking it to the intervention, and underpinned by data from various designs. However, the overall level was brought down from 'strong' by limitations in the numeric data, which focused mainly on the skills underpinning participation, as opposed to the actual doing of it (the dimension emphasised as important in the textual data).

Self-care

Self-care emerged initially only from the numeric data, with related textual data identified after a subsequent targeted search; overall data on the concept was limited. In textual data, descriptions of self-care outcomes were brief comments referring to increased ability to undertake basic tasks related to looking after oneself (e.g. eating or drinking), and to decreased need for caregiver assistance. These were in the voices of children, parents and researchers; we found no comments about self-care outcomes from professionals:

> *(. . .) without it, I could do almost nothing. (. . .) Even eat by myself, I cannot without sitting in my chair.*
>
> *Child, Pituch* et al.[100]

> *(. . .) who would have thought that you could have gotten up and got water [to drink] on your all-terrain vehicle?*
>
> *Parent, Feldner* et al.[60]

> *In turn, [powered mobility] decreased the level of assistance required from caregivers and the need to wait for others' availability.*
>
> *Researcher, Pituch* et al.[100]

TABLE 15 Support for the concept of participation, play and social interactions as an outcome of a powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept very clearly reflects the textual data from the primary studies, but numeric data are restricted mainly to underlying skills	Low
Explanation credibility	The concept of participation (including participation in play and social interactions) is well established, and was expected to emerge as a key outcome of powered mobility (reflected in the pre-review logic model). The included studies provided evidence of two credible hypotheses of mechanisms through which this outcome might link to powered mobility intervention, namely 'movement and mobility' and 'fit'	Strong
Weakness minimisation	The concept is supported by numeric and textual data from different study designs (RCTs, observational, qualitative, mixed methods), but the numeric data focus mainly on the underlying skills. Some of the numeric measures have significant limitations	Moderate
Inside–outside	There is substantial convergence in the accounts across all stakeholders, including the child and parent (insider) views and professional and researcher (outsider) views	Strong
Publication bias	There are studies that show non-significant results	Strong
Additional comments	None	N/A

N/A, not applicable.

In the numeric data, self-care outcomes were assessed mainly in very young children, with all studies using the PEDI (*Table 16*). The results were mixed, but reported an overall consistent message that, although powered mobility may not directly change children's skills in self-care, it may reduce the need for caregiver assistance by enabling a child's sense of independence and control.

The assessment of certainty for the concept indicated overall low support for self-care as a powered mobility intervention outcome (*Table 17*); this reflected the overall limited data available for this concept. Furthermore, owing to the limited data, we were not able to explore variation by age.

Autonomy, independence, choice and control, and freedom

Autonomy, independence, choice and control, and freedom were a broad cluster of concepts that emerged primarily from the textual data, and were repeatedly represented in the voices across children, parents, professionals and researchers. They were often articulated and framed through specific incidents of movement, mobility, participation and self-care that the different stakeholders attended to as observable manifestations of the abstract, desirable states of being autonomous, independent and free, and having choices, controls and self-expression:

> *Going through the door, getting outside. That's very cool – I mean, talk about freedom (. . .) that is an entrance to his own world. There are no limitations on that.*
>
> *Parent, Durkin*[109]

> *It's given her far more freedom, independence. To go out with friends, she doesn't need someone.*
>
> *Parent, Evans* et al.[59]

> *Learning to use a power mobility device also altered how children were able to express themselves.*
>
> *Researcher, Kenyon* et al.[61]

TABLE 16 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'self-care' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'self-care'	No change in 'self-care'	Negative change in 'self-care'		
Study population aged < 5 years	• Self-care (PEDI self-care subscale) (Jones *et al.*;[13] *n* = 1) • Daily activities (PEDI-CAT daily activities domain) (Kenyon *et al.*;[75] *n* = 1) • Self-care (PEDI self-care subscale) (Logan *et al.*;[88] *n* = 1)	• Self-care (PEDI self-care subscale) (Huang *et al.*;[17] *n* = 1) • Self-care (PEDI self-care subscale), developmental skills (BDI adaptive subscale) (Jones *et al.*;[14] *n* = 28) • Daily activities (PEDI-CAT daily activities domain) (Kenyon *et al.*;[75] *n* = 1) • Self-care with caregiver assistance (PEDI self-care subscale) (Agrawal *et al.*;[63] *n* = 15)	N/A	42.9 (3)	??
Study population aged ≥ 5 years	N/A	Self-care (WeeFIM) (Kornafel *et al.*;[104] *n* = 1)	N/A	0 (0)	0

N/A, not applicable; PEDI-CAT, Pediatric Evaluation of Disability Inventory – Computer Adaptive Test; WeeFIM, Functional Independence Measure for children.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 17 Support for the concept of self-care as an outcome of a powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	Both numeric and textual data clearly reflected the analytical concept, but these data were limited in breadth. Numeric data were absent for a part of the study population (children aged ≥ 5 years)	Low
Explanation credibility	The concept of self-care is well established in practice, although published evidence and theories are limited. The included studies provide some early hypotheses about how self-care might be influenced by powered mobility interventions; these require further investigation, which may also result in refinement of the concept	Low
Weakness minimisation	The concept was supported by limited numeric and textual data from a small pool of study designs (observational, qualitative)	Low
Inside–outside	The concept was reflected in child and parent (insider) views and in researcher (outsider) observations, but not in professionals' (outsider) views	Moderate
Publication bias	There is at least one study that shows non-significant, null or contrasting results	Strong
Additional comments	None	N/A

N/A, not applicable.

> *Analysis of interview responses revealed that nine young people and their families (50%) mentioned increased independence as a result of the EPIOC.*
>
> *Researcher, Evans* et al.[59]

We explored the data for differences between the age groups. In the textual data, there was variation in the nature of activities and decisions in which the children expressed their autonomy, freedom, choice and control, and independence; this nature appeared to relate to the children's developmental stage. Yet, the descriptions of the actual abstract concepts remained consistent across age groups. One specific, repeated example of this was children, across ages, using powered mobility to express their autonomy, choice and control by defying demands and expressing anger or disagreement. This included, for example, deliberately driving away or crashing into objects or people, and was often, but not always, interpreted by parents, professionals and researchers as positive and as developmentally appropriate self-expression:

> *I think the best picture I have of him is driving away from me. I get tears every time I see it because he's on his own and he's able to get somewhere by himself without any help.*
>
> *Parent, Wiart* et al.[102]

> *So it's quite interesting to see there is a personality now whereas before, you didn't realize was quite a little naughty streak and someone who actually wanted to go quite fast.*
>
> *Professional (occupational therapist), Sonday and Gretschel*[101]

> *Running over people's toes, hitting walls, (. . .) purposely being naughty because (it) is developmentally appropriate to be . . . naughty (. . .).*
>
> *Professional, Kenyon* et al.[61]

Numeric data related to this concept cluster focused mainly on two aspects within the broad cluster: (1) children's increased self-initiation (as a manifestation of control, choice and independence) and (2) reduced caregiver assistance (as a manifestation of independence) (*Table 18*). Of these, the latter overlapped with the self-care data.

TABLE 18 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'autonomy, independence, choice and control, and freedom' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'autonomy, independence, choice and control, freedom'	No change in 'autonomy, independence, choice and control, freedom'	Negative change in 'autonomy, independence, choice and control, freedom'		
Study population aged < 5 years	• Frequency of self-initiated communications and physical interactions with objects (coding of behaviour from video samples), frequency of self-initiated communications with caregiver (coding of behaviour from video samples), frequency of self-initiated changes of location in space (coding of behaviour from video samples) (Butler;[89] *n* = 6) • Caregiver assistance (PEDI caregiver assistance subscale) (Jones *et al.*;[13] *n* = 1) • Responsibility (PEDI-CAT responsibility subscale) (Kenyon *et al.*;[75] *n* = 1) • Development in motor, cognitive, language and social skill domains (PEDI) (Stokes *et al.*;[92] *n* = 1) • Upright, independent locomotion (textual, descriptive data) (Flodin;[122] *n* = 1)	Responsibility (PEDI-CAT responsibility subscale) (Kenyon *et al.*;[75] *n* = 1)	N/A	83 (5)	++
Study population aged ≥ 5 years	• Self-initiated movement (counts of self-initiated movement with no physical assistance determined by video-recordings) (Deitz *et al.*;[12] *n* = 2) • Level of assistance child requires to perform different tasks (therapist evaluation form), amount of assistance child requires to move between the cart and other furniture (therapist evaluation form) (Gehant;[108] *n* = 11) • Health-related quality of life (CPCHILD) (Kenyon *et al.*;[76] *n* = 1)	N/A	N/A	100 (3)	++
Study population aged < and ≥ 5 years	• Achievement of goals related to independence and autonomy (parent ratings of whether goals were fully, partly or not achieved) (Evans and Baines;[62] *n* = 90) • Effects of having a powered wheelchair as perceived by parents (questionnaire and 5-point scale) (Home and Ham;[106] *n* = 57) • Number of switch and joystick inputs by the child (count of number of inputs per test) (Kakimoto *et al.*;[107] *n* = 2) • Social development (textual data) (Odor and Watson;[91] *n* = 13)	N/A	N/A	100 (4)	++

CPCHILD, Caregiver Priorities and Child Health Index of Life with Disabilities; N/A, not applicable; PEDI-CAT, Pediatric Evaluation of Disability Inventory – Computer Adaptive Test.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

The assessment of certainty for the concept indicated overall low support for autonomy, independence, choice and control, and freedom as powered mobility intervention outcomes (*Table 19*). Although the textual evidence was rich and converging, the theoretical focus and linking of the concepts was limited, as was the scope of the numeric data.

Psychological outcomes: sense of achievement, confidence, motivation and cognitive outcomes

Psychological outcomes of powered mobility for children were reported in relation to sense of achievement; a child's confidence and beliefs about capabilities, motivation and identity; and cognitive outcomes including alertness, language, communication and understanding. In textual data, descriptions of these concepts were present in the voices of parents, professionals and researchers, but not in the voices of the children themselves. The descriptions for sense of achievement, confidence and motivation were easier to find than descriptions of cognitive outcomes:

> *And she realized then: 'I thought initially I can't do it, but I tried and I can'.*
>
> *Parent, Sonday and Gretschel*[101]

> *[Researcher:] The family noted pride and self-efficacy (. . .) Teresa [parent] narrated, 'He had just driven and a bunch of people were telling him how amazing he was and that was his response. That smile was just, like, proud.' When Sam [child] described the photo, he narrated, 'I drive. In the gym, I'm happy'.*
>
> *Researcher, parent and child, Kenyon* et al.[60]

> *Observed effects judged to be the result of the training included increased wakefulness and alertness, (. . .) John sometimes arrived at the training sessions asleep or acting very tired, but as he was being positioned in the powered wheelchair, he would straighten up and look around.*
>
> *Researcher, Nilsson and Nyberg*[74]

The numeric data for achievement, motivation and confidence suggested a consistently positive impact across age groups (*Table 20*). The achievement data were from measures that require families to uniquely generate items, limiting the interpretation of this finding. The motivation data were based on mastery motivation. The cognitive outcome measurement emphasised language and communication skills, and the data suggested a positive impact (*Table 21*). There were insufficient data to draw conclusions about differences in responses in the psychological outcomes based on age.

TABLE 19 Support for the concept of autonomy, independence, choice and control, and freedom as outcomes of a powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept clearly reflects the textual data; the numeric data relate to a narrower segment of the overall concept	Low
Explanation credibility	This is an elaborate cluster of several inter-related and overlapping concepts that are broadly recognisable, but that, in their current format in the included evidence, lack clear, specific links to wider theories and evidence	Very low
Weakness minimisation	The data supporting the concept come from a range of study designs (observational, qualitative, mixed methods), but include limited experimental data	Moderate
Inside–outside	The data consisted of child and parent (insider) views, and professionals' and researchers' (outsider) views and observations	Strong
Publication bias	There was at least one study that showed non-significant results	Strong
Additional comments	None	N/A

N/A, not applicable.

TABLE 20 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'achievement, motivation and confidence' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'achievement, motivation and confidence'	No change in 'achievement, motivation and confidence'	Negative change in 'achievement, motivation and confidence'		
Study population aged < 5 years	• Goal achievement (GAS), child performance in achieving functional goals set by a physical therapist (weekly activity log recorded by parents) (Huang *et al.*;[79] *n* = 29) • Mastery motivation (DMQ) (Kenyon *et al.*;[86] *n* = 3) • Mastery motivation (DMQ), spectrum of electroencephalography activity (electroencephalography equipment) (Kenyon *et al.*;[75] *n* = 1) • Desire of children to use powered wheelchair (questionnaire) (Uyama and Hanaki;[112] *n* = 318) • Mastery pleasure (DMQ-18, Chinese version) (Huang *et al.*;[80] *n* = 29) • Self-image (textual, descriptive data) (Flodin;[122] *n* = 1)	N/A	N/A	100 (6)	++
Study population aged < and ≥ 5 years	• Goal achievement in activities of daily living (COPM) (Bottos *et al.*;[23] *n* = 29) • Effects of having a powered wheelchair as perceived by parents (questionnaire and 5-point scale) (Home and Ham;[106] *n* = 331) • Child motivation (textual data, video-coding) (Odor and Watson;[91] *n* = 13)	N/A	N/A	100 (3)	++

COPM, Canadian Occupational Performance Measure; DMQ, Dimensions of Mastery Questionnaire; DMQ-18, revised Dimensions of Mastery Questionnaire; GAS, goal attainment scaling; N/A, not applicable.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 21 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'cognitive outcomes' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'cognitive outcomes'	No change in 'cognitive outcomes'	Negative change in 'cognitive outcomes'		
Study population aged < 5 years	• Family perceptions of the training programme (weekly activity log) (Huang *et al.*;[79] *n* = 29) • Developmental skills (BDI receptive communication subscale) (Jones *et al.*;[14] *n* = 28) • Cognition, receptive language, expressive language (BSID) (Lynch *et al.*;[66] *n* = 1) • Cognition (BDI cognitive subscale, Merrill Palmer Revised cognitive subscale) (Mockler *et al.*;[111] *n* = 31) • Development in motor, cognitive, language, and social skill domains (PEDI, BSID) (Stokes *et al.*;[92] *n* = 1) • Communication skills, specific communication skills (questionnaire) (Uyama and Hanaki;[112] *n* = 318)	• Social/cognitive scaled score (PEDI social/cognitive subscales) (Kenyon *et al.*;[75] *n* = 1) • Developmental skills (BDI cognitive subscale) (Jones *et al.*;[14] *n* = 28)	N/A	85.7 (6)	++
Study population aged ≥ 5 years	Health-related quality of life (CPCHILD) (Kenyon *et al.*;[76] *n* = 1)	N/A	N/A	100 (1/1)	+
Study population aged < and ≥ 5 years	• Effects of having a powered wheelchair as perceived by parents (questionnaire and 5-point scale) (Home and Ham;[106] *n* = 57) • Vocalisations, smiling (total number recorded throughout the experiment) (Lovett;[113] *n* = 4) • Communication, mobility (textual data, video observation) (Odor and Watson;[91] *n* = 13)	Intellectual development (Leiter International Performance Scale Performance IQ score, Peabody Developmental Verbal Scale Verbal IQ score) (Bottos *et al.*;[23] *n* = 29)	N/A	75 (3)	++

N/A, not applicable.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

The assessment of certainty for the concept indicated overall low support for achievement, motivation and confidence as powered mobility intervention outcomes (*Table 22*), and indicated moderate support for cognitive outcomes as an outcome (*Table 23*). For achievement, motivation and confidence, the overall rating was low, primarily because of the limited data and the lack of a clear theory about linking these outcomes to powered mobility interventions in the included studies. Although the data were assessed as being more supportive of the cognitive outcomes, it is worth emphasising that there was no direct, high-quality evidence of effectiveness.

TABLE 22 Support for the concept of psychological outcomes of sense of achievement, confidence and beliefs about capabilities, and motivation as powered mobility outcomes

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept reflected the underpinning numeric and textual data, but overall data were limited	Low
Explanation credibility	The concepts of confidence, achievement and motivation are well established and sound; the evidence to support their linkage to powered mobility intervention in the present review was limited	Low
Weakness minimisation	The concept was supported by limited numeric and textual data from a small pool of study designs (observational, qualitative). Outcome measurement in several of the studies had significant limitations	Very low
Inside–outside	The data consisted primarily of parent (insider) and professional (outsider) views and researcher (outsider) observations	Moderate
Publication bias	There was a lack of contrasting results	Low
Additional comments	None	N/A

N/A, not applicable.

TABLE 23 Support for the concept of cognitive outcomes as an outcome of the powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept clearly reflects the numeric data from the primary studies; examples in textual data are limited	Low
Explanation credibility	Potential impact of self-directed movement on cognitive development is an established hypothesis. The concept, as it was synthesised and presented in much of the primary studies, covered a number of subcategories of cognition (e.g. language, attention), which could plausibly be differentially affected by a use of powered mobility; this was not further explored	Moderate
Weakness minimisation	The concept is supported by a range of numeric and textual data from different study designs (RCT, observational, qualitative). The contribution from qualitative designs was limited	Moderate
Inside–outside	The data related to the concept consists of mainly outsider views and observations. For this concept, the requirement of insider (child) voice was assessed as being of lesser importance, and potentially something that is not feasible to gain in younger children; it was noted that the data included detailed, direct observations explicitly designed to capture cognitive engagement from the child perspective	Moderate
Publication bias	There was at least one study that showed non-significant results	Strong
Additional comments	Although there was consistent and cumulative evidence of possible impact on at least some cognitive outcomes, the size of these effects and the precise aspect of cognitive function remains to be clarified	N/A

N/A, not applicable.

Safety outcomes: emotional consequences, accidents and pain

The included studies did not include straightforward negative safety outcomes. Instead, the information relevant to safety outcomes was more nuanced, akin to considerations about benefits and risks of powered mobility interventions. The data clustered around two themes: (1) emotional consequences and (2) accidents and pain.

Emotional consequences of powered mobility for the parent and child

Child and parent feelings were frequently reported to change as a result of powered mobility intervention. For parents, both negative feelings (anxiety, distress, sadness) and positive feelings (relief, happiness, joy) were reported. These feelings were not necessarily mutually exclusive, but could coincide within a parent for the same event, as well as two parents feeling the opposite way about the same event. One common example of a trigger for emotions in parents was the initial proposal for, and prescription of, powered mobility by professionals. The emotional consequences varied; negative feelings were reported in several papers:

> *The power wheelchair was the really big step, although when we first started talking wheelchairs and they had said, 'Oh, possibly a power wheelchair', I got my back up, thinking going in a manual wheelchair was hard enough.*
>
> *Parent, Wiart* et al.[102]

> *When the idea of a power chair was presented (. . .) that actually was a great source of relief for me and it was a good thing.*
>
> *Parent, Wiart* et al.[102]

As children progressed to try the powered mobility equipment, to learn to use it and to actually use it, parents were described to often report more positive emotions. These were often reported to relate to parents observing their child gaining control, freedom, independence and self-expression (see *Autonomy, independence, choice and control, and freedom*) in everyday situations:

> *For example, Sam set his own mobility agenda (. . .) He tells me 'No, mommy, I want to go here' . . . to even be able to talk back to me – it makes me want to cry, in a good way.*
>
> *Parent, Feldner* et al.[60]

> *The process of learning to use powered mobility was recognized as an emotionally charged undertaking for all those involved. Some parents expressed joy or excitement at seeing their child use a power mobility device. Other parents expressed a mix of emotions.*
>
> *Researcher, Kenyon* et al.[61]

For emotional consequences on the children, there was some evidence about a trajectory of feelings related to learning to drive powered mobility:

> *Participants reported that children learning to use a power mobility device may experience a wide range of emotions from excitement and joy, to pride in being able to move and do for themselves, to frustration, anxiety, and despair.*
>
> *Researcher, Kenyon* et al.[61]

However, most data related to everyday situations that the children experienced. One example was the experience of fear and worry related to road traffic, even in older children, who may have been expected to feel safe in such situations:

> *(. . .) he wouldn't have any chance at all if someone was to hit him. He doesn't feel safe to go up the road. He goes out with someone with him, but he's sixteen years old. He should really feel alright to go out by himself.*
>
> *Parent, Evans* et al.[59]

Similar data were identified in relation to general worries and fears about any accidents that might result in the child losing control of the powered mobility equipment:

> *I just said 'I'm not doing this on me own' because if it skids I'm gonna be really scared.*
>
> *Child, Gudgeon and Kirk*[99]

Further triggers of negative emotions in children described in the data were other people and their actions, and problems in fit between the child and the child's environment. These could frustrate and upset children using powered mobility:

> *You feel quite frustrated you're just sitting there and next minute this person walks right in front of you (. . .) like 'Did you not see me sat there?' you know what I mean, it's frustrating.*
>
> *Child, Gudgeon and Kirk*[99]

> *Liam was particularly frustrated and upset at the time of the interview as he had been unable to go on the bus to swimming with his classmates as his EPIOC could not be transported and he described the whole experience as 'crap' (. . .).*
>
> *Researcher, Gudgeon and Kirk*[99]

In the numeric data, feelings were mainly operationalised through parenting stress and child enjoyment (*Table 24*). For both of these, positive impact was consistently reported for very young children and from mixed-age studies. There was only one relevant study[12] for children aged ≥ 5 years, and that reported no effect.

The assessment of certainty for the concept indicated overall low support for emotional consequences as powered mobility intervention outcomes (*Table 25*). It was noted that the textual data supporting this concept were rich in detail, and converged around similar themes; however, further theory development of these themes was limited, as were numeric data. It was also noted that the data underpinning the emotional consequences concept were, at least in part, overlapping with the autonomy, independence, choice and control, and freedom concept cluster, and that the boundaries or processes through which these concepts connected were not clear.

Accidents and pain

The data in the review included descriptions of accidents and pain resulting from the use of powered mobility equipment. The accidents related mainly to the child losing control of the equipment. This could be an accident due to the environment not being a good fit for the child's use of the equipment or due to the human factors in the environment (*Table 26*):

> *Erm I crushed Oliver and Elliot at school once because my arm got stuck and then I flied forward into them.*
>
> *Child, Gudgeon and Kirk*[99]

> *Especially when he's driving with his chin, which is how he drives. He's not actually gripping the control with his hand. His head flies off and he loses control of the chair if the terrain is rough.*
>
> *Parent, Evans* et al.[59]

The percentage of children reported to have experienced accidents during real-world use was similar in very young and older children (30% and 31.5%, respectively), and the descriptive examples were also similar. No data were found to substantiate the concerns about traffic-related risks (see *Emotional consequences of powered mobility for the parent and child*).

TABLE 24 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'safety outcomes: emotional consequences' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'safety outcomes: emotional consequences'	No change in 'safety outcomes: emotional consequences'	Negative change in 'safety outcomes: emotional consequences'		
Study population aged < 5 years	• Caregivers' perceived stress level (Parenting Stress Index) (Huang and Chen;[77] $n = 20$) • Family's perception of how much child enjoyed each driving activity (fun index) (Huang *et al.*;[17] $n = 1$) • Parenting stress (Parenting Stress Index) (Huang *et al.*;[79] $n = 29$) • Parent perceptions of child enjoyment during driving sessions (fun index, daily activity log) (Logan *et al.*;[87] $n = 3$) • Parent perceptions of child enjoyment (fun index, daily activity log), socialisation (number of positive facial expressions including smiling and laughing; number of negative facial expressions including signs of discomfort, unhappy expressions and crying) (Logan *et al.*;[88] $n = 1$) • Fun (fun index) (Logan *et al.*;[87] $n = 4$)	N/A	N/A	100 (6)	++
Study population aged ≥ 5 years	• Pain or discomfort related to the intervention (Questionnaire) (Frank *et al.*;[131] $n = 74$) • Safety (total number of collisions that occurred in a trial), joystick move, intervention level (on-board monitoring device) (Zeng *et al.*;[82] $n = 5$)	Affect (number of observations for which positive affect was recorded for each child, percentages of moments for which positive affect was recorded for each child) (Deitz *et al.*;[12] $n = 2$)	N/A	66.6 (2)	?

continued

TABLE 24 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'safety outcomes: emotional consequences' concept (*continued*)

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'safety outcomes: emotional consequences'	No change in 'safety outcomes: emotional consequences'	Negative change in 'safety outcomes: emotional consequences'		
Study population aged < and ≥ 5 years	• Parental perception of the level of their child's disability (semistructured interview), parental and child acceptance of the powered wheelchair (semistructured interview) (Bottos *et al.*;[23] *n* = 29) • Attitude of children when using the rehabilitation tool (qualitative assessment of degree of stress and excitation) (Ceres *et al.*;[120] *n* = 5) • Effects of having a powered wheelchair as perceived by parents (questionnaire and 5-point scale) (Home and Ham;[106] *n* = 57) • Health-related quality of life (CPCHILD) (Kenyon *et al.*;[76] *n* = 1) • Psychosocial (social, emotional) development (parent report) (Paulsson and Christoffersen;[95] *n* = 12) • Enjoyment (frequency count of positive/negative facial expressions) (Logan *et al.*;[118] *n* = 3) • Child motivation (textual data, video coding) (Odor and Watson;[91] *n* = 13)	N/A	Enjoyment (frequency count of positive/ negative facial expressions) (Logan *et al.*;[118] *n* = 3)	100 (7)	++

CPCHILD, Caregiver Priorities and Child Health Index of Life with Disabilities; N/A, not applicable.

a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 25 Support for the concept of safety outcomes (emotional consequences) as an outcome of the powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept reflects the textual data; the numeric data relate to a narrower segment of the overall concept	Low
Explanation credibility	The concept mirrors an existing theory and evidence-based concepts (e.g. affect, feeling, emotion), but in the present data there was little explicit linkage of these concepts or bodies of knowledge, and limited unpicking of the mechanisms that may link emotions to the intervention	Low
Weakness minimisation	The data supporting the concept come from a range of designs (observational, qualitative) across a number of studies	Moderate
Inside–outside	The data related to the concept consisted of child and parent (insider) views and researcher (outsider) observations	Moderate
Publication bias	There is at least one study with contrasting results	Strong
Additional comments	It was noted that some of the textual data supporting this concept were particularly rich in detail, and consistent from across a number of studies. Data linked to this concept were, at least in part, the same as data linked to the autonomy concept cluster	N/A

N/A, not applicable.

TABLE 26 Results from non-comparative, comparative and survey studies for verbatim outcomes mapped to the 'safety outcomes: accidents and pain' concept

Study population	Summary outcomes
Study population aged < 5 years	Safety (reported by authors):[119] the power of the cart is sufficient to move the child, but not sufficient to cause injury to family members, furniture or the child himself. The large wheel spacing and low centre of gravity make tipping over unlikely
	Accidents during powered wheelchair use (questionnaire prepared by the study authors):[112] 30% of facilities reported that accidents were present during powered wheelchair use, 61% reported that accidents were absent and 9% were unknown. Specific details of the accidents were collisions with indoor obstacles (reported by 18.2% of facilities), collisions with outdoor objects (reported by 9.1%), collisions with people (reported by 9.1%), falls from the wheelchair (reported by 27.3%), falls related to uneven surfaces (reported by 18.2%); running into a ditch on a public road (9.1%); and other (9.1%). There was no significant increase in the number of facilities that experienced an accident during powered wheelchair use, despite increased demands by children to have more time to use powered wheelchairs in some facilities
Study population aged ≥ 5 years	Number of collisions (supervisor observations):[130] the number of collisions decreased when the child used the mid-wheel drive chair to perform all three tasks. Collisions while moving through a doorway decreased from six to one; while manoeuvring through three cones, collisions decreased from five to two; and while manoeuvring in the hallways, collisions decreased from six to two
	Number of collisions (supervisor observations):[85] there were six collisions that required the intervention of the supervisor to free or unblock the wheelchair. Three of them were due to system failures, and the rest were due to the sensory capabilities of the robot
Study population aged < and ≥ 5 years	Accidents (parent questionnaire):[106] when parents were asked if their child had ever had an accident in the equipment, 39 said no and 18 said yes. The variety of comments from those who said yes included a range of accidents and injuries, including trapped fingers, falling off kerbs, broken bones, damage to furniture and buildings, tipping and so on
	Accidents/incidents (parent report):[95] three incidents happened in more than 1 year. None of the children was hurt in the incidents
	Safety (questionnaire administered to intervention recipients):[91] the Smart Wheelchair described as a safe learning environment for physically, cognitively and perceptually impaired children

Beyond accidents, there was also evidence in the textual data that powered mobility equipment could cause pain and discomfort to the child; one commonly mentioned reason was sitting in the equipment for a long time:

> *Analysis of the 'in-depth' interviews indicated that 38 (59%) users described ways in which they felt their pain was influenced by their EPIOC and 19 (30%) reported pain or discomfort aggravated by sitting.*
>
> *Researcher, Frank* et al.[131]

> *Due to certain school policies where children are left in wheelchairs all day long, she is bound to experience pain and discomfort and yes, she does complain of it sometimes. Juddering happens just going along the road because of so many holes in the pavement.*
>
> *Parent, Evans* et al.[59]

The assessment of certainty for the concept indicated low support for accidents and pain as powered mobility intervention outcomes (*Table 27*). Although the nature of accidents and pain were well described, the prevalence data came from a limited pool of studies, and, within those studies, came mainly from parents.

Mixed-methods framework synthesis: factors associated with feasibility and acceptability

In addition to the six outcome concepts and two safety concepts, three further concepts were identified in relation to feasibility and acceptability of powered mobility (*Table 28*): (1) 'fit' and opportunities for everyday use, (2) social environment and (3) physical environment. These were often reported as being inextricably linked to the outcomes, processes and contexts of powered mobility use, and to the issues of acceptability and feasibility. *Table 29* presents the powered mobility evidence profile from the mixed-methods synthesis.

TABLE 27 Support for the concept of safety outcomes (accidents and pain) as an outcome of the powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept clearly reflected both the numeric and textual data from the primary studies	Strong
Explanation credibility	Both aspects of the concept (accidents and pain) are clearly articulated and operationalised for measurement. Mechanisms through which they may relate to powered mobility interventions are described	Strong
Weakness minimisation	The concept is supported by data from a limited pool of studies of different designs (observational, qualitative)	Low
Inside–outside	The data related to the concept consist mainly of parent reports	Low
Publication bias	Several studies reported accidents. It is unclear whether or not absence of reports of no accidents constitutes publication bias	Moderate
Additional comment	Some of the accident data included in the studies came from experimental studies; however, the primary focus of assessment of certainty in the present review relates to the data from pragmatic studies reporting accidents resulting from everyday real-world use	N/A

N/A, not applicable.

TABLE 28 Summary descriptions, and the boundaries, of the key feasibility and acceptability concepts identified from the review

The concept (related papers)	Summary description	Included in the concept	Excluded from the concept
'Fit' and opportunities for everyday use (quantitative studies;[55,83,96,98,132] qualitative studies[59–61,71,99–103,109])	The fit as a dynamic 'coming-together' of the child, powered mobility equipment, and the child's everyday social, physical and policy environment	• Physical and psychological compatibility between the child, the powered mobility equipment and the environment • Fundamental transformations related to the child's own or perceived identity resulting from the interactions between the child, the powered mobility and the environment • Includes the concepts of 'new self' and 'integrated self'	• Excludes the consequences of good fit, which have been coded separately (e.g. participation, choice, control, accidents, emotions and pain) • Excludes descriptions of the people or environments around the child, which have been coded separately
	Opportunities to use powered mobility in everyday situations	• Includes the possible openings for the child to use powered mobility in everyday life • Includes changes in physical spaces, resources or daily routines, and dynamic interactions between the child, their environment and daily activities	Excludes the actualisations of the possibilities, for instance the actual use of powered mobility (coded under 'movement and mobility') and the subsequent outcomes (coded under 'participation, freedom, etc.')
Social environment (quantitative studies;[91,96,98] qualitative studies[59,61,99,101,102])	Characteristics and actions of other people, social rules and norms, policies and practices that either shape or are shaped by the child's use of powered mobility	• Includes other people, policies, social rules and norms, social structures, informal and implied policies and practices, and stated rules and policies • Includes positive and negative impacts ('facilitators' of and 'barriers') to powered mobility use, user experience and outcomes • Includes practical implications of child's powered mobility on other people and social structures, such as the ways in which powered mobility can make activities easier or more difficult for other people	Excludes professionals and service provision, and emotions of other people (coded under 'emotional consequences')
Physical environment (quantitative studies;[91,106,132] qualitative studies[59–61,99,100,102])	Built and natural physical surroundings and spaces that shape a child's use of powered mobility	• Includes insides and outsides of buildings, and related access; under-tyre conditions, such as ice, mud, potholes and kerbs; road safety and traffic; and weather • Includes child's interactions with these elements	Excludes social environment; see row above

TABLE 29 Powered mobility evidence profile from the mixed-methods synthesis (process outcomes)

The outcome concept	Number of studies per design	Number of participants across studies	Evidence about the importance of the outcome	Overall quality of evidence
'Fit' and opportunities for everyday use	• Qualitative = 10 • Observational = 5	797	Critical	Low
Social environment	• Qualitative = 5 • Observational = 3	111	Insufficient evidence	Very low
Physical environment	• Qualitative = 6 • Observational = 3	216	Insufficient evidence	Very low

'Fit' and opportunities for everyday use

The concept of 'fit' was explicitly labelled and articulated in only one qualitative paper;[99] others implied this concept and illustrated it in examples:

> *Using an EPIOC was an experience which required active involvement from [the child] as they worked to balance, or achieve an adequate fit, between their own abilities, desires and needs; those of their parents and friends; the demands of the environment; and the capabilities and limitations of the EPIOC itself.*
>
> *Researcher, Gudgeon and Kirk*[99]

As a synthesised concept across the included data, fit can be described as a coming-together of three elements: (1) the child, (2) the equipment and (3) the child's social, physical and policy environments. Fit is dynamic in that it changes with any of the three elements, and it is a spectrum, that is there are degrees of better and worse fit. Achieving a sufficiently good fit was repeatedly described as a necessary condition for a child's use of powered mobility, and as something that a child needed to seek to constantly negotiate:

> *It depends, say err if it's like a test and there's a massive space I'll probably go in (to the classroom in the equipment) (. . .) but say it's a small one I'll just maybe like drive into the doorway and leave it there.*
>
> *Child, Gudgeon and Kirk*[99]

Restrictions in fit were reported to translate to suboptimal powered mobility use and outcomes, and an increased likelihood of negative emotional consequences. In contrast, a good fit had the potential to transform a child's movement, mobility and participation:

> *He just sailed on into the camp meeting area where registration was, and he was going around (. . .) chatting with everybody. I was just blown away, because I had never, ever understood that David had the capacity nor would have the opportunity to do something like that.*
>
> *Parent, Sonday and Gretschel*[101]

Good fit required psychological, social and physical compatibility. The psychological compatibility was described in terms of the child's self-identity; the social compatibility was described in terms of the way others viewed the child. In this, using powered mobility in everyday life required both the child and those around the child to develop a new sense of what the child is like and what the child can do and actually does in everyday life. From this reframing, a new 'integrated self' of the child emerged, both in the child's own mind and in the eyes of others:

> *The children perceived that the 'self' that existed before they had (the powered mobility) did not adequately fit the environment, and hence they were prevented from fulfilling their needs and desires. In contrast, using (powered mobility) was seen as allowing a new self to emerge, one that integrated their body and (powered mobility).*
>
> *Researcher, Gudgeon and Kirk*[99]

> *It (powered wheelchair) changed his peers' attitudes toward him because they saw that he could do something on his own and that he could actually think on his own.*
>
> *Parent, Wiart* et al.[102]

> *You start to see your child in a different light and they start to see themselves in that light (. . .).*
>
> *Parent, Kenyon* et al.[61]

Furthermore, this change in the perceptions about the child was often described to be a catalyst for more opportunities for the child to use the powered mobility and to actualise further positive outcomes in terms of participation and independence:

> *Learning to use a power mobility device often changed the way that the participants and others perceived a child (. . .) Such changes in how a child was perceived often led to increased opportunities for social interaction and participation and expanded the child's growing sense of independence and responsibility.*
>
> *Researcher Kenyon* et al.[61]

> *He can go out and wander around the playground with the kids, do everything within his ability that the other kids do, and they don't look at him as, 'Oh, God, we have to push the wheelchair'. (. . .) They look at him as a whole person.*
>
> *Parent (mother), Wiart* et al.[102]

Numeric data on fit and opportunities were very limited (*Table 30*), and an overall impression from the data was that fit was a concept emerging from the child and parent narratives, but was less well recognised in professional and researcher narratives. In professional narratives, the focus of fit was

TABLE 30 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'fit' and opportunities for 'everyday use' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'fit' and opportunities for 'everyday use'	No change in 'fit' and opportunities for 'everyday use'	Negative change in 'fit' and opportunities for 'everyday use'		
Study population aged < 5 years	• Independent mobility in the classroom (coded from video-recordings) (Ragonesi *et al.*;[96] *n* = 1) • Independent mobility in the classroom (coded from video-recordings) (Ragonesi *et al.*;[83] *n* = 1)	N/A	Cost of assistive technology [Cost (US$) of assistive technology purchases per annum] (Bamer *et al.*;[55] *n* = 538)	66.7 (2)	+
Study population aged ≥ 5 years	• Longitudinal use or disuse of powered mobility (interview questions) (Wiart *et al.*;[132] *n* = 66) • Child knowledge, skills, beliefs and feelings (quotations from participants) (Sharma and Morrison;[98] *n* = 35)	N/A	N/A	100 (2)	+

N/A, not applicable.
a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

often limited to adapting the powered mobility equipment set-up to the point where the child was able to drive it, with limited evidence of broader consideration of fit in the wider sense of compatibility between the child, the equipment and their everyday environment:

> *Several participants described the individualized nature of equipment needs as a 'Catch-22' in which proper equipment and set-up were necessary to enable a child to use a power mobility device, but a child needed to actually use the power mobility device to discover what equipment and set-up were needed (. . .).*
>
> *Researcher, Kenyon* et al.[61]

Both the numeric and textual data suggested that it was possible to achieve a good fit in very young children, as well as across age groups, but that this required careful consideration of a child's wider social and physical environment. The evidence related to these is further summarised in the next two sections on social and physical environment. The assessment of certainty for the concept indicated overall low support for 'fit' and opportunities for everyday use (*Table 31*); the key limitations were the small pool of data and the lack of theory integration.

Social environment: the people and policies around the child

Previous sections have already illustrated ways in which people and policies around the child can shape their powered mobility use and outcomes (e.g. see concepts in *Emotional consequences of powered mobility for the parent and child* and *'Fit' and opportunities for everyday use*). As a specific concept, social environment mainly emerged from, and was supported by, textual data (*Table 32* presents a summary of the quantitative findings).

TABLE 31 Support for the concept of 'fit' and opportunities for everyday use, as factors associated with the feasibility and acceptability of powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept clearly reflects the textual data from the primary studies; numeric data are limited	Low
Explanation credibility	The analytical concept is theoretically novel in the field, and was explicitly discussed mainly in just one study. More broadly, the concept mirrors biopsychosocial frameworks of disability and functioning (e.g. by the WHO), which position everyday functioning as a successful coming-together of the person, the health condition and related interventions, and the wider environment. As presented in this review and the included data, the concept lacks clarity and is not directly measurable	Low
Weakness minimisation	The concept is supported by data from a limited pool of studies of different designs (observational, qualitative)	Low
Inside-outside	The data related to the concept consisted of child (insider) and parent and researcher (outsider) views, and researcher (outsider) observations	Moderate
Publication bias	Rated one step down from strong, as the interaction between the person and their environment is widely discussed among the research community; this was not reflected in the included publications related to this concept	Moderate
Additional comments	None	N/A

N/A, not applicable; WHO, World Health Organization.

TABLE 32 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'social environment' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'social environment'	No change in 'social environment'	Negative change in 'social environment'		
Study population aged < 5 years	Socialisation in the classroom, defined as the amount of time the child spent interacting with peers and teachers in the classroom (coding from video footage) (Ragonesi *et al.*;[96] *n* = 1)	N/A	N/A	100 (1)	+
Study population aged ≥ 5 years	Parent feelings (quotations from participants) (Sharma and Morrison;[98] *n* = 35)	N/A	Feasibility issues (quotations from participants) (Sharma and Morrison;[98] *n* = 35)	50 (1)	?

N/A, not applicable.
a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

Broadly, the social environment concept covered two dimensions. The first dimension was the people and social structures (informal policies, rules, practices) as shapers of children's use of powered mobility, their user experiences, and the related outcomes. These influences could be negative or positive:

> *The power that adults have to override the children's autonomy by disabling their powered mobility equipment – switching the equipment off or by turning down the speed – was clear (. . .).*
>
> *Researcher, Durkin*[109]

> *Rocky explained how another child had caused a crash: 'Sometimes people touch (the EPIOC) 'cos there was somebody called Oscar and he drove my chair . . . once he made me go head first into the wall, head forwards (. . .)'.*
>
> *Researcher and child, Gudgeon and Kirk*[99]

> *Due to certain school policies where children are left in wheelchairs all day long, she is bound to experience pain and discomfort and yes, she does complain of it sometimes.*
>
> *Parent, Evans* et al.[59]

The second dimension was the reciprocal impact of children's powered mobility use on other people and social structures. Common examples were the perceptions that a child's powered mobility use can make things easier for others, and has the power to fundamentally change how children with disabilities are perceived:

> *The children also perceived that these gains in independence were beneficial in reducing the need for others to help them. In fact Farrah indicated that this was her main reason for using her EPIOC (. . .).*
>
> *Researcher, Gudgeon and Kirk*[99]

> *His mother perceived the identification of her family's needs and the opportunity of her community members to assist in meeting these needs as a positive step toward a better understanding of disability issues and a step toward interdependence in her community.*
>
> *Researcher, Wiart* et al.[102]

The assessment of certainty for the concept indicated overall very low support for social environment (*Table 33*), due to limitations in the volume and diversity of data, and lack of clear links to theory.

Physical environment

Similarly to social environment, the concept of physical environment had very limited dedicated data and has already been illustrated in previous sections (e.g. see the concepts *Accidents and pain* and *'Fit' and opportunities for everyday use*); furthermore, the data underpinning it were largely textual (*Table 34*).

The features of the physical environment described in the data included access, built spaces and other built features (especially kerbs and potholes), natural environment and the impact of weather (especially issues related to ice and mud), and road safety and traffic. The data originated primarily from children's and parents' voices, and focused largely (although not exclusively) on descriptions of physical environment as a barrier.

The assessment of certainty for the concept indicated overall very low support for physical environment (*Table 35*) due to limitations in the volume and diversity of data, and lack of clear links to theory.

Qualitative thematic synthesis: preparation, provision, use and expectations

From the separate synthesis of all qualitative evidence from the qualitative studies and relevant mixed-methods studies ($n = 21$), 17 descriptive themes were developed, comprising 60 subthemes. These were mapped onto four care processes and outcome contexts (*Table 36*).

TABLE 33 Support for the concept of social environment as a factor associated with the feasibility and acceptability of powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept clearly reflects textual data from the primary studies; there are a lack of numeric data	Very low
Explanation credibility	The role of social environment as a factor in intervention feasibility and acceptability is well established; however, the consideration of that idea in the included studies was very limited	Very low
Weakness minimisation	The concept was supported from a small pool of qualitative studies	Very low
Inside–outside	The data related to the concept consists of child (insider) and parent (outsider) views, but no objective observations	Very low
Publication bias	Rated down because the importance of social environment in implementation of powered mobility interventions is widely discussed among the research community (e.g. conference presentations); this was not reflected in the included publications related to this concept	Low
Additional comments	None	N/A

N/A, not applicable.

TABLE 34 Results from quantitative studies (comparative studies and surveys) for verbatim outcomes mapped to the 'physical environment' concept

Study population	Verbatim outcomes (outcome measure) (reference, sample size)			% (*n*) of studies reporting positive change	Summary code[a]
	Positive change in 'physical environment'	No change in 'physical environment'	Negative change in 'physical environment'		
Study population aged < 5 years	Home affordances (Affordance in the Home Environment for Motor Development – Toddler version – Chinese version) (Huang *et al.*;[80] *n* = 3)	N/A	N/A	100 (1)	+
Study population aged ≥ 5 years	Pain or discomfort related to the intervention (questionnaire) (Frank *et al.*;[131] *n* = 74)	N/A	N/A	100 (1)	+
Study population aged < and ≥ 5 years	• Effects of having a powered wheelchair as perceived by parents (survey) (Home and Ham;[106] *n* = 57) • Locations of environmental barriers and facilitators to powered mobility use (interview questions) (Wiart *et al.*;[132] *n* = 66)	N/A	N/A	100 (2)	+

N/A, not applicable.
a 0 = no effect (0–33% of studies suggest an effect); ? = inconsistent (34–59% of studies suggest an effect); + = positive effect (60–100% of studies suggest a positive effect); – = negative effect (60–100% of studies suggest a negative effect); when three or more studies suggested the same result, summary codes were 00, ++, – –; when four or more studies suggested inconsistent results, the summary code was ??.

TABLE 35 Support for the concept of physical environment as a factor associated with the feasibility and acceptability of powered mobility intervention

Concept support criteria	Assessment of support	Level of support
Truth value/bias	The analytical concept reflects textual data from the primary studies; there are a lack of numeric data	Very low
Explanation credibility	The role of physical environment as a factor in intervention feasibility and acceptability is well established; however, the consideration of that idea in the included studies was very limited	Very low
Weakness minimisation	The concept was supported from a small pool of studies of different designs (observational, qualitative)	Low
Inside–outside	The data related to the concept consists of child (insider) and parent (outsider) views, but no objective observations	Very low
Publication bias	Rated down because the importance of social environment in implementation of powered mobility interventions is widely discussed among the research community (e.g. conference presentations); this was not reflected in the included publications related to this concept	Low
Additional comments	None	N/A

N/A, not applicable.

TABLE 36 Summary of themes from qualitative thematic synthesis

Context: care processes and outcomes	Descriptive themes	Subthemes	Studies contributing to subthemes
Preparation	Preparing for powered mobility	Education and information for parents and children	Pritchard-Wiart *et al.*,[58] Feldner *et al.*,[60] Durkin[109] and Berry *et al.*[133]
		Skill preparation	Pritchard-Wiart *et al.*,[58] Evans and Baines,[62] Torkia *et al.*,[71] Durkin[109] and Currier *et al.*[105]
		Emotional journey for parents and children	Feldner *et al.*,[60] Kenyon *et al.*,[61] McGarry *et al.*,[69] Pituch *et al.*,[100] Wiart *et al.*,[102] Feldner,[116] Cerruti and Biondi[103] and Cronin[134]
	Conceptualising intervention	Defining aims and goals	Evans and Baines,[62] Nilsson and Nyberg[74] and Cerruti and Biondi[103]
		Change in intervention conceptualisation over time	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] McGarry *et al.*,[69] Wiart *et al.*[102] and Cerruti and Biondi[103]
Provision	Assessment	Consulting stakeholders throughout provision process	Kenyon *et al.*,[61] Pituch *et al.*[100] and Berry *et al.*[133]
		Conflict between therapist and caregiver	Durkin,[109] Wiart *et al.*,[102] and Berry *et al.*[133]
		Providing information and choice	Evans *et al.*[59] and Durkin[109]
		Defining eligibility	Evans *et al.*[59] and Durkin[109]
		Impact of bureaucracy on provision	Evans *et al.*,[59] Pituch *et al.*[100] and Feldner[116]
		Variance in assessment and provision between different services	Feldner *et al.*,[60] Pituch *et al.*,[100] and Feldner[116]
	Training and skill development	Experiential learning through use and play	Kenyon *et al.*,[61] Evans and Baines,[62] Durkin,[109] Pituch *et al.*,[100] Currier *et al.*[105] and Nilsson *et al.*[117]
		Importance of time to develop skills and reveal potential	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] Evans and Baines,[62] Nilsson and Nyberg,[74] Durkin,[109] Sonday and Gretschel,[101] Currier *et al.*,[105] Jonasson[110] and Berry *et al.*[133]
		Defining learning continuums	Kenyon *et al.*,[61] Evans and Baines[62] and Durkin[109]
Use	Accessibility	Accessibility of public spaces	Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Wiart *et al.*,[102] Feldner[116] and Berry *et al.*[133]
		Terrain	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Gudgeon and Kirk,[99] Pituch *et al.*[100] and Berry *et al.*[133]
		Accessibility of home environments	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] Evans and Baines,[62] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Wiart *et al.*[102] and Berry *et al.*[133]
	Usability	Size, weight and manoeuvrability of device	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Wiart *et al.*,[102] Feldner,[116] Cerruti and Biondi[103] and Berry *et al.*[133]

TABLE 36 Summary of themes from qualitative thematic synthesis (*continued*)

Context: care processes and outcomes	Descriptive themes	Subthemes	Studies contributing to subthemes
		Logistics of transporting device	Evans *et al.*,[59] Kenyon *et al.*,[61] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Wiart *et al.*,[102] Cerruti and Biondi[103] and Berry *et al.*[133]
		Support from school/ nursery to use device	Kenyon *et al.*,[61] Evans and Baines,[62] Durkin,[109] Gudgeon and Kirk,[99] Pituch *et al.*[100] and Berry *et al.*[133]
		Appearance of device	Pritchard-Wiart *et al.*,[58] Evans *et al.*[59] and Gudgeon and Kirk[99]
	Integration	Achieving fit between child, device and environment	Kenyon *et al.*,[61] Gudgeon and Kirk[99] and Pituch *et al.*[100]
		Device becomes child's 'legs'	Evans *et al.*,[59] Gudgeon and Kirk,[99] Pituch *et al.*[100] and Berry *et al.*[133]
	Safety	Concerns about safety to child and others	Evans *et al.*,[59] Kenyon *et al.*,[61] Evans and Baines[62] Durkin,[109] Gudgeon and Kirk,[99] Pituch *et al.*[100] and Berry *et al.*[133]
		Balancing perceived and actual risks	Evans and Baines,[62] and Gudgeon and Kirk[99]
		Adverse weather conditions	Kenyon *et al.*,[61] Evans and Baines[62] and Pituch *et al.*[100]
		Accidents affect confidence	Evans *et al.*,[59] and Gudgeon and Kirk[99]
	Postural support and seating	Postural support and seating	Evans *et al.*,[59] Feldner[116] and Berry *et al.*[133]
	Maintenance and review	Adapting device as child grows	Evans *et al.*,[59] Frank *et al.*[131] and Berry *et al.*[133]
		Ongoing review and maintenance	Evans *et al.*[59] Pituch *et al.*[100] and Berry *et al.*[133]
		Poor maintenance affects use and outcomes	Evans *et al.*[59] Feldner,[116] Frank *et al.*[131] and Berry *et al.*[133]
Outcomes (anticipated and experienced)	Independence	Independence and autonomy	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Cerruti and Biondi,[103] Jonasson[110] and Cronin[134]
		Freedom	Evans *et al.*,[59] Feldner *et al.*,[60] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*[105] and Feldner[116]
		Self-efficacy	Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Jonasson[110] and Cronin[134]

continued

TABLE 36 Summary of themes from qualitative thematic synthesis (*continued*)

Context: care processes and outcomes	Descriptive themes	Subthemes	Studies contributing to subthemes
	Self	Self-expression through movement and choice	Feldner *et al.*,[60] Kenyon *et al.*,[61] Durkin[109] and Jonasson[110]
		Disobedience and risky behaviours	Feldner *et al.*,[60] Kenyon *et al.*,[61] Durkin,[109] Feldner[116] and Cerruti and Biondi[103]
		Confidence and esteem	McGarry *et al.*,[69] Gudgeon and Kirk[99] and Feldner[116]
		Agency over body	Feldner *et al.*,[60] Kenyon *et al.*,[61] Gudgeon and Kirk[99] and Feldner[116]
		Device becomes negative symbol	Kenyon *et al.*[61] and Wiart *et al.*[102]
	Participation	Taking part in valued activities	Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Cerruti and Biondi[103] and Cronin[134]
		Facilitating age-appropriate play	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Evans and Baines,[62] McGarry *et al.*,[69] Durkin,[109] Sonday and Gretschel,[101] Wiart *et al.*[102] and Feldner[116]
		Broadening horizons	Feldner *et al.*,[60] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*[102] and Currier *et al.*[105]
		Frustration resulting from restriction	Gudgeon and Kirk[99] and Pituch *et al.*[100]
		Exploratory behaviour	Feldner *et al.*,[60] Evans and Baines,[62] Sonday and Gretschel,[101] Wiart *et al.*[102] and Feldner[116]
	Social	Social interaction	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Cerruti and Biondi[103] and Cronin[134]
		Acceptance among peers	Wiart *et al.*,[102] Feldner[116] and Cerruti and Biondi[103]
	Emotions	Fun and joy	Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Nilsson and Nyberg,[74] Durkin,[109] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Feldner,[116] Cerruti and Biondi[103] and Jonasson[110]
		Joy of movement	Pritchard-Wiart *et al.*,[58] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Nilsson and Nyberg,[74] Kirk,[99] Pituch *et al.*,[100] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner[116] and Jonasson[110]
		Improving frustration and positive affect	Evans and Baines,[62] McGarry *et al.*[69] and Feldner[116]

TABLE 36 Summary of themes from qualitative thematic synthesis (*continued*)

Context: care processes and outcomes	Descriptive themes	Subthemes	Studies contributing to subthemes
	Development	Emotional development	Durkin[109] and Jonasson[110]
		Communication	Pritchard-Wiart *et al.*,[58] McGarry *et al.*,[69] Currier *et al.*[105] and Jonasson[110]
		Learning cause and effect	Pritchard-Wiart *et al.*,[58] Evans and Baines,[62] McGarry *et al.*,[69] Nilsson and Nyberg,[74] Currier *et al.*[105] and Nilsson *et al.*[117]
		Initiative and motivation	Pritchard-Wiart *et al.*,[58] McGarry *et al.*,[69] Sonday and Gretschel[101] and Currier *et al.*[105]
		Interaction and attention to stimuli	McGarry *et al.*,[69] Nilsson and Nyberg[74] and Nilsson *et al.*[117]
	Impact on others	Reduce burden on parent/ family	Evans *et al.*,[59] Evans and Baines,[62] Pituch *et al.*,[100] Wiart *et al.*,[102] Jonasson[110] and Berry *et al.*[133]
		Sharing in child's joy and accomplishment	Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines[62] McGarry *et al.*,[69] Wiart *et al.*,[102] Currier *et al.*,[105] Cerruti and Biondi[103] and Jonasson[110]
		Changing other's expectations for child	Kenyon *et al.*,[61] McGarry *et al.*,[69] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*[105] and Feldner[116]
		Family togetherness	Evans and Baines[62]
		Parental independence	Evans *et al.*,[59] Evans and Baines[62] and Jonasson[110]
		Parental loss of control	Kenyon *et al.*,[61] Evans and Baines[62] and Cerruti and Biondi[103]

From the 17 descriptive themes, five analytical themes were developed, which moved beyond the descriptive themes to provide new theoretical insights not seen in individual primary studies. These were as follows:

1. children's and parents' emotional journeys towards acceptance of powered mobility
2. experiential learning and play to support a continuum of powered mobility skill development
3. the importance of parent and therapist time and support to realise the full potential of powered mobility
4. fit between the child, device and environment influences the child's sense of self and identity
5. children's independence, freedom and self-expression as key outcomes of powered mobility.

In the following sections, we focus on reporting the analytical-level themes relating to the feasibility, acceptability and anticipated outcomes of powered mobility. Quotations are taken directly from papers and are used as illustrative examples for the analytical themes. For each quotation, relevant study information is presented for context, including the respondent (i.e. child, parent, therapist), child condition/diagnosis, child age and relevant type of powered mobility device. For cases for which the specific information about the respondent was not recorded, we present the study sample details instead.

Children's and parents' emotional journeys towards acceptance of powered mobility

The experiences of children and families concerning the proposal and acceptance of powered mobility varied greatly, on a broad spectrum, from very positive to very negative.[60,61,69,100,102,103,116,134] One mother

of a boy with cerebral palsy described seeing her son use powered mobility for the first time at age 5 years as the 'best and worst day of her life' owing to the contrast between the child's joy and her own beliefs about powered mobility as a symbol of disability.[61] Some parents expressed reluctance in seeking and accepting powered mobility;[69,103] conversely, physiotherapists could also be a source of hesitation.[102] The children in the studies had a wide range of diagnoses and mobility needs; some children had deteriorating life-limiting conditions, whereas others did not, which created different contexts towards acceptance of powered mobility. For some parents, the transition to powered mobility was traumatic, uncertain or difficult to accept,[61,102,103,134] and prompted an often emotional re-evaluation of their expectations and hopes for their child:[61,100,102,134]

> *I was still thinking, 'Okay, maybe one of these days, he'll get up and he'll walk, and we don't need this.' Then going into a power wheelchair, it was kind of a realization that 'No, he isn't going to be able to walk,' (. . .) So it was a little tough.*
>
> *Parent of a child with cerebral palsy or myelomeningocele, aged 10–18 years, powered wheelchair users, Wiart* et al.[102] *Specific characteristics of the individual being quoted are not reported in the paper*

Some parents held on to the hope that their child would one day walk, and therefore saw powered mobility as a 'last resort';[61,102] thus, the offer or provision of powered mobility symbolised a significant change in their life and a powerful symbol of loss or change.[61,100,102] This appeared to be particularly relevant for children with higher skills and abilities, for instance one parent of a child with Duchenne muscular dystrophy stated that their child's transition to powered mobility at age 7 years was a negative symbol of the child's reduced independence:[61]

> *He . . . caught on (quickly to driving a power wheelchair but) . . . for him, I think (driving a power wheelchair is) a degenerative ability . . . I think his obstacles (to using a power mobility device) are (going to) come.*
>
> *Father of a 13-year-old male with Duchenne muscular dystrophy, powered mobility device user from age 7 years, Kenyon* et al.[61]

Interestingly, one parent described using a powered ride-on toy to avoid or postpone their child needing a wheelchair.[116] The process of adjustment to powered mobility can be a source of conflict between parents and therapists/clinicians, resulting from different levels of knowledge and expectations for the child.[102,109,133] The emotional journey for the child and family is an important part of the provision process and should be seen as a key factor for (either a facilitator of or barrier to) intervention effectiveness, particularly for children who need prolonged support and facilitation to get the most out of their powered mobility:

> *Viewpoints of parents and therapists often varied (. . .) One informant sarcastically told the interviewer: 'I think that they're (the footstraps are) useless . . . But then I am not a professional. All I am is her mother and all I have been doing is just watching her and helping her at night . . .*
>
> *Berry* et al.[133] *(Parents of children with cerebral palsy, myelomeningocele or other diagnosis, aged 5–23 years, powered wheelchair users)*

Children need emotional and practical support through this journey, as the transition to powered mobility can be stressful and full of uncertainty. This requires support from parents and other institutions (i.e. school, social services) to promote confidence and engagement with the learning and provision process, and to let children know that their opinion is valid:

> *Parent 4 noted that the process of learning powered mobility was very emotional for her child: 'how are people going to treat me? . . . Will I be able to do it? . . . What if I get stuck?' There are so many (emotions).*
>
> *Parent of 7-year-old male with cerebral palsy, powered mobility device user from age 3 years, Berry* et al.[133]

The development of skills helps children to take agency over the process and motivates continued engagement and ownership.[61,74,105,109] Likewise, parental observation of the child's development and achievement is emotionally rewarding and vindicates the decision to progress with powered mobility:[69,105]

> *I've always been very hesitant about a motorised wheelchair for lots of different reasons, but seeing her do this and that she is able to do it, I think has changed my view of the whole thing.*
>
> *Mother of 6-year-old female with spastic diplegia involving both spasticity and dystonia, smart-wheelchair user[69]*

This emotionally charged experience requires early support from services to help families make the transition. This can be facilitated by early provision of information about what powered mobility may offer, and early education, assessment and training for parents/children to promote better understanding of each child's long-term potential through powered mobility.[58,102,133]

Experiential learning and play to support a continuum of powered mobility skill development

The learning of powered mobility is not initially about learning to drive; there is an important distinction between the process of learning movement and driving a powered mobility device. Children must first understand the concept of movement, then the relationship between their movement and the movement of their device.[61,62,109] They can then begin to understand the relationship between their movement and the space/environment around them:

> *The developmental learning process now needs to be viewed as a continuum from understanding the concept of movement, understanding how the machine works, through to using the machine as part of attaining a desired lifestyle.*
>
> *Durkin[109] [Children with cerebral palsy or hypoxic brain damage (and their clinicians/therapists), aged 5–12 years, powered wheelchair users]*

The learning process in and of itself can have benefits for children, such as encouraging response to stimuli and developing a sense of cause/effect.[58,62,69,74,101,105,117] The act of practising and training helps children to refine their skills and begin to integrate the device into their own sense of movement and space:

> *After a few sessions she started to look intensely at her hand when it was placed on the joystick. Both children seemed to react more to external stimuli and to show more interest in persons and objects in their vicinity.*
>
> *Researcher observations of children with profound cognitive disabilities, aged 4–5 years, powered wheelchair users, Nilsson and Nyberg[74]*

Experiential learning is key to developing mobility skills, and requires real-world use of aids and time to develop skills.[61,62,100,105,109,117] Bumping, crashing and receiving feedback on movement can help children to understand the relationship between their movement and the world around them.[109] During the introduction of powered mobility and training, the process should be framed as an opportunity for children to play, explore and engage in fun activities at their own pace.[61,69,101,109] Adult conceptualisations of movement should be avoided, and training should not be focused on teaching children how to 'drive'.[109] As noted by Durkin,[109] very young children benefit from powered mobility interventions that are framed as toys and opportunities to play, thus highlighting the importance of chronologically and developmentally age-appropriate interventions:

> *When the powered wheelchair appearance was changed by producing a front facade of a well-known children's character the parents responded very positively which encouraged the children (. . .) As the 12- to 18-month-old children approached 18 months they became more reluctant to enter the powered wheelchair for play.*
>
> *Durkin[109] [Children with cerebral palsy or hypoxic brain damage (and their clinicians/therapists), aged 5–12 years, powered wheelchair users]*

Although continuums of skill development are specific to each child, children tend to follow a trajectory of, first, understanding cause and effect and the concept of movement; second, developing purposeful movement; third, gaining basic control of powered mobility (i.e. directional movement and stopping); fourth, developing spatial awareness; and, finally, utilising powered mobility to facilitate lifestyle goals.[61,62,109] It is important that, as part of a powered mobility intervention, the development of mobility and driving skills is started at a very early stage of the process, for instance as a preparatory stage. The development of controlled, safe movement was described as the first stage towards promoting long-term independence and autonomy:

> *Spinning and experiencing the joy of movement were identified as common first steps. Understanding cause and effect, developing a sense of purposeful movement, driving in the real world, and responding to multiple attentional demands were identified as some of the quintessential points in learning.*
>
> *Kenyon* et al.[61] *(Parents and therapists of children with arthrogryposis multiplex congenita, acquired brain injury, cerebral palsy or Duchenne muscular dystrophy; the mean age at powered mobility device use commencement was 3 years)*

An important omission is the evaluation of young children's readiness for powered mobility; a standard approach to assessing readiness for powered mobility in young children is not apparent from the existing qualitative evidence.

The importance of parent and therapist time and support to realise the full potential of powered mobility

The powered mobility needs and abilities of each child are highly variable, and it can take time for them to be revealed.[58,61,62,74,101,109,110,133] Early promotion of skill development and individually tailored interventions can help children to achieve their full potential. It is therefore important that children are given adequate time to learn and practise powered mobility:

> *We have to give of our time, believe in their ability and really see that this is happening for that person. If we don't put this effort into the kids they will quit driving eventually. Abilities may therefore be lost (. . .).*
>
> *Jonasson[110] [Parents and therapists of 'severely disabled' children, age not specified, smart powered wheelchair users (AKKA-board)]*

The relationship between a child's abilities, impairments and potential to benefit from powered mobility may not be apparent until after powered mobility has already been introduced.[58,74,109] Therefore, powered mobility loan or trial schemes could help to identify children who may benefit from powered mobility, but who would have otherwise been overlooked:

> *John was, in the beginning, assessed as having a better potential for driving than Anna. The results, however, clearly showed us how wrong this assessment had been. It was Anna who had the greater potential, but that potential was masked by her restricted ability to move her arms and hands.*
>
> *Researcher observations of children with profound cognitive disabilities, aged 4–5 years, powered wheelchair users, Nilsson and Nyberg[74]*

Because of the high degree of variance between children in terms of their chronological and developmental age, abilities, needs and potential to benefit, 'there's no recipe'[61] to guide provision; therefore, individualised approaches to assessment, provision and training are required.[61,100,133] This, in turn, requires a commitment of time and co-operation from clinicians/therapists, parents and other key stakeholders to ensure that the intervention meets the unique needs of each child:

> *I think (that) some people strive to have (a recipe to teach children how to use a power mobility device), but (a recipe) doesn't work . . . (the recipe is) . . . whatever works (for each) individual . . . Parents and therapists recognized the importance of involving all stakeholders (. . .).*
>
> *Occupational therapist of children with arthrogryposis multiplex congenita, acquired brain injury, cerebral palsy or Duchenne muscular dystrophy (mean age at powered mobility device use commencement was 3 years), Kenyon* et al.[61]

Strict eligibility criteria may be counterproductive, and clinicians/therapists should instead be given adequate time to conceptualise the intervention as a means to promote a better lifestyle for the child and their family, rather than solely as a means to mobilise the child:[99,109]

> *Clinicians should be given time to assess the children and problem-solve in a more holistic way, which is led from the perspective of giving the child and family a 'lifestyle' rather than just a piece of mobility equipment.*
>
> *Durkin[109] [Children with cerebral palsy or hypoxic brain damage (and their clinicians/therapists), aged 5–12 years, powered wheelchair users]*

Both clinicians and parents can act as facilitators of a child's development of mobility and independence, rather than as directors or supervisors. Durkin[109] defined this role as being a 'responsive partner'; children should be allowed to direct their exploration and skill development, with careful and subtle encouragement/support from responsive partners, to allow children to develop at their own pace and under their own volition:

> *The children gave clear messages about how they liked to learn the skills for powered mobility; the importance of exploring and being able to do things on their own; not being watched; learning in a 'cool' way; taking the lead in how they played and learnt.*
>
> *Durkin[109] [Children with cerebral palsy or hypoxic brain damage(and their clinicians/therapists), aged 5–12 years, powered wheelchair users]*

The support and advocacy of institutions around the child is key to ensuring that the intervention can be optimised. For instance, schools can play an important role in supporting children to use and learn powered mobility.[61,62,99,100,109] Without this support, sceptical or risk-averse institutions can detrimentally affect the powered mobility intervention, and thus affect a child's potential. To maximise the effectiveness of interventions, physical and attitudinal adaptation may be required, and influential institutions need to be educated about safety and potential benefits. This could form part of the intervention, through a holistic approach to assessment, provision and training. Evans and Baines[62] found that interventions for very young children failed when schools and parents did not fully engage from the outset:

> *He was happy to try it but lack of fine motor skills and dystonia meant his usage remained limited to large flat grassed areas . . .*
>
> *Parent of a child with cerebral palsy, spinal muscular atrophy, global developmental delay, arthrogryposis, spina bifida, aged 15–72 months, starter powered mobility device users, Evans and Baines.[62] Specific characteristics of the individual being quoted are not reported in the paper*

> *Unfortunately critical school staff did not support the use of Wizzybug and did not follow through with regular use of it to help her master these skills.*
>
> *Parent of a child with cerebral palsy, spinal muscular atrophy, global developmental delay, arthrogryposis, spina bifida, aged 15–72 months, starter powered mobility device users, Evans and Baines,[62] Specific characteristics of the individual being quoted are not reported in the paper*

Fit between the child, device and environment influences the child's sense of self and identity

Powered mobility devices were conceptualised by some parents[133] and children[59,99,100] as being a child's 'legs'. This integration of self and device illustrates a process of adaptation that allows a child's 'new self' to emerge as a result of powered mobility and independent movement.[99] This is an important concept for therapists and clinicians to take account of, as powered mobility can become integral to

the child as they become increasingly independent and able to engage with the world around them on their own terms:

> *Children perceived that the 'self' that existed before they had an EPIOC did not adequately fit the environment, and hence they were prevented from fulfilling their needs and desires. In contrast using an EPIOC was seen as allowing a new self to emerge, one that integrated their body and EPIOC.*
>
> *Gudgeon and Kirk[99] [Children with cerebral palsy, muscular dystrophy, spinal muscular atrophy or brain tumour (or their parents), aged 7–16 years, powered wheelchair users]*

One of the key barriers to powered mobility use is access. This is particularly relevant in public spaces, which are often poorly designed for powered mobility use.[59–61,99,100,102,116,133] Access can also be an issue in home settings, owing to issues of space and adaptation.[58,61,62,99,100,102,133] Restricted access impedes children's opportunities to participate in activities[59–61,99,100,102,116,133] and to integrate powered mobility into daily life.[99,100] Powered mobility interventions can attempt to actively address these barriers by taking into account the home and public environment in which the child exists:

> *(. . .) children's increased sense of liberty was dependent upon and directly limited by environmental obstacles: 'life when you have an electric wheelchair is still a lot more complicated, due to society, not necessarily because of the wheelchair' (. . .) Mothers identified various obstacles in the community, notably architectural barriers.*
>
> *Pituch* et al.*[100] (Parents of children with skeletal dysplasia, osteogenesis imperfecta, spinal muscular atrophy, arthrogryposis or cerebral palsy, aged 12–18 years, powered wheelchair users)*

The logistical issues of transporting powered mobility devices adds another layer of complexity, as a result of the size and weight of such devices.[59,61,99,100,102,103,133] In some circumstances, families may be deterred from using powered mobility outside common settings (such as home and school) because of practical or financial barriers to transportation:[61]

> *Most young people did transport their EPIOCs. However, nearly all said that the chair was heavy and cumbersome to take in the family vehicle, thus limiting the chair's use away from home.*
>
> *Evans* et al.*[59] [Children with muscular dystrophy, cerebral palsy or other diagnoses (or their parents), aged 10–18 years, EPIOC users]*

Poor fit between the child, device and environment is a major barrier to participation, which, in turn, causes frustration, isolation and affects mood and self-efficacy.[59,99,100,133] Furthermore, poor fit can lead to reduced safety and to risks of harm to the child and people around the child.[59,61,62,100] This requires children and parents to be continually alert and vigilant, particularly in public spaces. The negative experience of accidents/injury can have a detrimental impact on the confidence of children, leading to fear, anxiety or a reluctance to use powered mobility:[59,99]

> *Even minor mishaps may affect children's confidence in the chairs. Many young people said they did not always feel safe in the chair.*
>
> *Evans* et al.*[59] [Children with muscular dystrophy, cerebral palsy or other diagnoses (or their parents), aged 10–18 years, EPIOC users]*

In contrast, minor bumps and crashes can also be a positive learning experience, and can help children to refine physical driving skills.[109] A balance is needed between encouraging regular use of powered mobility and managing potential safety concerns. For some children, their sense of safety may be too limited to allow unsupervised use of powered mobility,[59,109] but this does not mean that they cannot benefit from supervised powered mobility use. Furthermore a child's initial inability to adequately

control a powered mobility device does not indicate an inability to benefit from powered mobility or to develop control at a later date:[74]

> *Sometimes an individual's ability and potential are difficult to assess because of his or her profound disabilities. In such cases 'driving to learn' may help to make the underlying potential more apparent. The training may reveal previously unrecognized abilities and determine an individual's full potential.*
>
> *Researcher observations of children with profound cognitive disabilities, aged 4–5 years, powered wheelchair users, Nilsson and Nyberg[74]*

The interface between the child, device and environment is complex and multifaceted,[61] and is also observed in dynamics between the child and wider society, for instance in the perceived stigma of powered mobility[100] and other mobility aids.[58] The appearance of powered mobility devices is also important to children,[59,99] highlighting the relationship between device and identity. Ongoing review and follow-up can ensure that devices are fit for purpose as a child grows, and as their needs change.[59,131,133] This requires close monitoring of children and devices, timely maintenance and a sensitivity for the child's sense of self and emerging personality.

Children's independence, freedom and self-expression as key outcomes of powered mobility

Independence was identified as an important powered mobility outcome in most studies,[58–62,69,99–103,105,110,116,134] and was related, to some extent, with many other outcomes. For instance, independence was related to social participation[58–62,69,99–103,105,116,134] and increased opportunities for play[58–60,62,69,101,102,105,116] and exploration.[58,60,62,101,102,116] The experience of independent movement for children who would not be otherwise mobile or independent can have a profound impact on a child and their family. Powered mobility is perceived to broaden a child's horizons as they begin to find new ways to interact with the world in age-appropriate ways:[60,100–102,105,116]

> *While Linda's reluctance to consider a wheelchair for Jamie reflects similar perceptions describing early responses to wheelchair use in the literature, both mothers also share the view that wheelchair and ride-on car function in 'opening up his world' so Sam and Jamie can play with siblings and peers more independently.*
>
> *Feldner* et al.*[60] (Parents of children with cerebral palsy, aged 4–5 years, powered wheelchair and ride-on toy users)*

Freedom was also an important outcome across the age range.[59,60,100–102,105,116] The concept of freedom related to a child's ability to control their chair, and the suitability of the environment to allow free movement and exploration, linking to the need to integrate child, device and environment. In younger age groups, caregiver vigilance is still required and may even increase when a child starts using powered mobility. However, child freedom can also spill over into positive impacts to the family and carers through the sharing of joy, reduced caring burden and more free time:[62,133]

> *Another parent reported: '. . . it allows her the freedom to go where she wants . . .'. Many parents used the word 'freedom' in describing what they liked the best about the chair. Freedom for the child helped to 'free up' time for the caregiver.*
>
> *Berry* et al.*[133] (Parents of children with cerebral palsy, myelomeningocele or other diagnosis, aged 5–23 years, powered wheelchair users)*

The wider family may begin to feel a sense of leading a 'normal family life'[62] as they begin to engage in more activities that involve the whole family in fun and play, thus facilitating a sense of family

togetherness.[62] Conversely, some parents felt a sense of losing control as a result of their child's newfound independence:[61,62,103]

> *I think it also means losing control as a parent . . . because now things can be run over in your house . . . it was a change to know that it was now happening in our lives . . .*
>
> *Mother of an 8-year-old male with cerebral palsy, powered mobility device user from age 5 years, Kenyon* et al.[61]

Self-expression through movement and behaviour can be an indicator of growing agency and self-efficacy.[60,61,109,110,116] The development of independent movement can create a positive feedback loop of growing confidence and motivation, which encourages the child to continue to develop and push the boundaries of their world.[60] This relates to the growing sense of self and integration of powered mobility and body. Children use their powered mobility devices to express themselves and to communicate through movement,[58,61,105,109,110] for instance moving away from tasks they do not want to do. They may also engage in risky behaviours and become disobedient as a means of pushing the boundaries of their world and expressing their newfound autonomy.[60,61,103,109,116] Although disobedience can be negative, it may also be indicative of a child participating in typical age-appropriate behaviour, and learning to makes choices and exert control. Therefore, a balance must be struck between encouraging age-appropriate behaviour and maintaining safety:

> *He tells me 'No, mommy, I want to go here' . . . to even be able to talk back to me – it makes me want to cry, in a good way.*
>
> *Mother of 5-year-old male with cerebral palsy, powered wheelchair user, Feldner* et al.[60]

> *It appeared that it was the act of directing their own mobility agenda that brought forward the changes in agency (. . .)*
>
> *Researcher, Feldner* et al.[60]

Synthesis of findings specifically relating to powered mobility for very young children

Seven studies referred specifically to children aged < 5 years and presented findings in such a way as to allow subgroup analysis of qualitative evidence;[58,60–62,74,105,116] four studies were related to ride-on toys;[58,60,61,116] three were related to powered wheelchairs;[61,74,105] and one was related to starter powered mobility devices.[62]

Very young children varied in their ability to control such devices; some children use these interventions as a means to promote independence and autonomy,[60–62,105] some use them to understand cause/effect and response to stimuli[58,62,74,105] and others use them to prepare for future powered mobility use,[58,62,105] although these were not always mutually exclusive. Early provision of powered mobility was described as an important factor in promoting better outcomes:

> *They need to be able to keep up to their age, and at one we're walking, we're exploring different things, so it's really no different. It's just a different way of doing it (. . .) It made us say 'absolutely he needs power mobility, right now! We can't waste time (. . .)'.*
>
> *Mother of 13-month-old male with arthrogryposis multiplex and hypotonia, ride-on toy user, Pritchard-Wiart* et al.[58]

The underlying conditions of the children and their related abilities appear to govern the purpose and potential of these interventions. This is an important distinction, as children can benefit from

using powered mobility devices even if the ultimate goal is not for them to be used completely autonomously, or as a means to be fully independent in their movement.[74] Parents may seek early powered mobility as a means to achieving benefits for the child in the future, which also links to parents' expectations and hopes:

> *When he gets older, he's going to have a better life because of the chair – because he has that independence. When he goes to school, he won't just be sitting in that chair; he'll be on the same level that children who can walk are on.*
>
> *Parent or grandparent of a child with cerebral palsy, myotubular myopathy or tetraphocomelia, aged 2–3 years, powered wheelchair user, Currier* et al.*[105]*
> *Specific characteristics of the individual being quoted are not reported in the paper*

The perception of powered mobility devices designed specifically for very young children is also of importance. For instance, the universality of ride-on toys and their close resemblance to age-appropriate toys means that children are not seen as 'different' when using them.[58] This also speaks to the stigmatising experience that mobility aid users report. Ride-on toys may therefore be more acceptable to parents and children, with some families even pushing back the need for a wheelchair as a result of ride-on toy use.[58] Ride-on toys and starter powered mobility devices may provide a gentler introduction to powered mobility that is more in tune with parental expectations:

> *It was kind of neat to give him the opportunity to have a toy that other typical kids in the neighbourhood have . . . and I liked that it didn't look obvious, as far as a tool for [children with] special needs, it was more subtle.*
>
> *Mother of 50-month-old male with cerebral palsy, ride-on toy user, Pritchard-Wiart* et al.*[58]*

Across all seven studies, it appeared that most very young children gain enjoyment and benefit from their powered mobility devices. It is of note that some starter powered mobility devices were returned unused;[62] reasons included the limited motor skills of the child, concerns about safety, poor access to the home, progression to walking rather than powered mobility and lack of parental time to facilitate use of the powered mobility. Likewise, some ride-on car users lost interest in the device over time or progressed to crawling instead.[58] Some negative outcomes of early powered mobility were noted from the parents' perspective, including parental feelings of loss of control of their child[61,62] and concerns about safety when the child used the powered mobility.[60–62] Conversely, parents also expressed that they were able to share in their child's joy[60–62,105,116] and that their expectations for their child improved.[61,105]

Summary of findings and GRADE-CERQual assessment

In the final stage of the thematic synthesis, we compared and contrasted the analytical themes to better understand the relationships between the themes and to develop a cohesive summary of the thematic synthesis findings. Subsequently, we developed key findings arising from the qualitative data relating to (1) the acceptance of powered mobility, (2) developing powered mobility skills and competency, (3) using powered mobility safely, (4) anticipated and experienced outcomes from powered mobility and (5) the overall benefit of powered mobility. Further description is provided in *Table 37*. For each of these key findings, we applied the GRADE-CERQual approach to assess overall confidence in the evidence supporting the findings (see *Table 37*). Full details of the GRADE-CERQual assessment are provided in *Appendix 10*, *Table 47*.

TABLE 37 Summary of findings and GRADE-CERQual assessment outcomes

Findings	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQual assessment
1. Acceptance of powered mobility		
1.1. Parents experienced both positive and negative emotions about their child transitioning to powered mobility. Although there was no clear difference in parental acceptance of powered mobility across the age range, parents of children with deteriorating conditions had more difficulty accepting powered mobility. In this specific context, powered mobility can be perceived as a negative symbol of a child's deteriorating condition and increasing disability, and thus affect initial parental acceptance	High confidence	Eight studies with moderate methodological limitations.[60,61,69,100,102,103,116,134] Minor concerns about coherence. No or very minor concerns about adequacy and relevance
1.2. Children did not commonly report issues with the acceptance of powered mobility, regardless of age, although very young children were seen to prefer toy-based interventions over powered wheelchairs. The process of learning to optimally use powered mobility can be stressful for older children	Low confidence	Two studies with minor methodological limitations.[61,109] Minor concerns about coherence and relevance. Serious concerns about adequacy
2. Developing powered mobility skills and competency		
2.1. Early introduction of powered mobility to very young children helped facilitate their development of powered mobility skills through playing and learning to use the powered mobility device. The same principle applied to older children, whereby early introduction of powered mobility provided a longer time frame to develop optimal skills and competency in using their powered mobility device. Early introduction of powered mobility promoted future powered mobility use and the attainment of children's lifestyle goals	Moderate confidence	Five studies with minor methodological limitations.[9,61,62,105,109] Minor concerns about coherence. Moderate concerns about adequacy due to limited data. No or very minor concerns about relevance
2.2. Regardless of age, children needed time and support to master powered mobility and benefited when they had the right device, an environment that was compatible for using the device freely and the motivation of those around them to facilitate use. Frequently, elements of the interface between child, device and environment are missing or inadequate	High confidence	Twelve studies with moderate methodological limitations.[58,61,62,74,99-101,105,109,110,116,133] No or very minor concerns about coherence and adequacy. Minor concerns about relevance
2.3. Children benefit from learning to use powered mobility through play and experiential learning. A child's potential to benefit from powered mobility may not become apparent until after powered mobility use. Powered mobility for very young children is conceptualised differently, as the primary purpose is to facilitate play and learning powered mobility skills through play	High confidence	Seven studies with minor methodological limitations.[58,61,62,100,105,109,117] Minor concerns about coherence and adequacy. No or very minor concerns about relevance
3. Using powered mobility safely		
3.1. Children's understanding and experience of safety in relation to powered mobility was different from that of their parents and therapists. Therapists and some parents were generally more risk averse than, especially older, children desired. Some children across the age range were frightened by bumps and accidents when using their powered mobility, whereas others learned from the experience. The conceptualisation of safety was mediated by a child's past experiences of accidents/injury and their age, level of development and cognitive abilities	Moderate confidence	Four studies with minor methodological limitations.[59,61,99,109] Moderate concerns about coherence and adequacy. Minor concerns about relevance

TABLE 37 Summary of findings and GRADE-CERQual assessment outcomes (*continued*)

Findings	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQual assessment
3.2. Safety concerns from parents and professionals were heightened when the child lacked an understanding of powered mobility safety owing to cognitive ability or young age. Some children had little concern for or an awareness of their safety when using their powered mobility. When a child lacked powered mobility safety awareness, parental concerns about safety were used as a reason for stopping their child from using and benefiting from their powered mobility device (especially in very young children). This decision to stop their child using their powered mobility was also connected to the requirement of parents (or other responsible adults) to be available to supervise children when using their powered mobility	Low confidence	Three studies with minor methodological limitations.[59,61,62] Moderate concerns about coherence. Serious concerns about adequacy due to limited, thin data. No or very minor concerns about relevance
3.3. Children can engage in risky or disobedient behaviours while using powered mobility. This behaviour was typically age appropriate and indicative of a child asserting control over their actions and behaviours, but may also put the child and other people at risk. The right balance must be achieved between facilitating a child's independent movement and maintaining safety, but this did not always appear to happen	Moderate confidence	Seven studies with minor methodological limitations.[60–62,99,103,109,116] Minor concerns about coherence. Moderate concerns about adequacy. No or very minor concerns about relevance
4. Anticipated and experienced outcomes from powered mobility		
4.1. A core set of anticipated and experienced outcomes overlapped across the age range, with independent mobility and a greater degree of independence as the predominant outcomes. Independent mobility and a greater degree of independence were linked to other key anticipated and experienced outcomes such as social participation, freedom and self-efficacy. A child's potential for independent mobility and increased independence using powered mobility were determined by their chronological and developmental age, and mediated by parental beliefs and attitudes towards powered mobility use and acceptance. There were subtle age-related differences in anticipated and experienced outcomes, particularly relating to parents' and children's desire for fun and enjoyment as outcomes in their own right for very young children	High confidence	Fifteen studies with moderate methodological limitations.[58–62,69,99–103,105,110,116,134] No or very minor concerns about coherence, adequacy and relevance
4.2. Although independent mobility and a greater degree of independence were key outcomes of powered mobility, not all children will achieve sufficient powered mobility control to become independent. For very young children and children with cognitive impairments, powered mobility can also be used to achieve developmental outcomes. Ability to achieve independent movement should not therefore be used as an explicit eligibility criteria for powered mobility provision	High confidence	Eight studies with moderate methodological limitations.[58,62,69,74,101,109,110,117] No or very minor concerns about coherence, adequacy and relevance

continued

TABLE 37 Summary of findings and GRADE-CERQual assessment outcomes (*continued*)

Findings	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQual assessment
4.3. Parents experienced both positive and negative outcomes associated with their child's increased mobility and associated independence. Parents share in their child's joy of being able to move independently, but may also experience a sense of losing control over the child	High confidence	Ten studies with moderate methodological limitations.[59–62,69,102,103,105,110,116] No or very minor concerns about coherence, adequacy and relevance
5. Overall benefit of powered mobility		
5.1. Although intended and experienced outcomes of powered mobility are conceptualised differently (with some overlap) before and after the age of 5 years, there was little discernible difference in the potential for children across the age range to benefit from powered mobility. Irrespective of age, earlier introduction of powered mobility has the potential to provide children with a longer time frame to potentially become skilled and competent in optimal powered mobility use, and therefore maximise their potential to benefit from it	High confidence	Sixteen studies with moderate methodological limitations.[58–62,69,99–103,105,109,110,116,134] No or very minor concerns about coherence, adequacy and relevance

Chapter 5 Review 2: review of the long-term consequences of independent mobility

The original aim of review 2 was to identify and synthesise quantitative, qualitative and mixed-method evidence to determine the long-term implications of self-directed or independent mobility for very young children (< 5 years), compared with older children (≥ 5 years).

To meet this aim, we developed and applied a search strategy to identify any studies that have investigated consequences of independent movement. Two broad facets were used to explore searching: (1) 'independent mobility' and (2) 'children or young people'. We defined independent movement to include crawling, cruising, etc., and to include any related outcomes.

The search resulted in > 47,000 potential papers. We had initially planned to screen these for inclusion/exclusion using an artificial intelligence algorithm; however, hand-screening of a proportion of the titles and abstracts identified no relevant papers to begin to develop an algorithm. We subsequently did a targeted search for economic studies looking at children with autism, Down syndrome, attention deficit hyperactivity disorder or cerebral palsy to inform the economic modelling. Although conditions such as autism and attention deficit hyperactivity disorder are not normally associated with mobility impairments and wheelchair use, some very young children with these conditions are provided with adapted buggies from an early age for a variety of reasons, including safety and posture. Therefore, these conditions were included in the search in case any broadly relevant economic data could be identified. This did not result in relevant papers. From this, we approached a targeted sample of our advisory group to search for any example papers that could be used as key texts to inform a further search and/or a development of an algorithm, but again we were not able to identify any.

Therefore, at this point, it has not been possible to systematically identify research studies related to the long-term benefits of independent mobility, and we are not able to confirm that such studies even exist outside the powered mobility field. This was reported to the funder during the study, and it was agreed that continuing with the review 2 was not feasible or of sufficient benefit.

From the review 1 search and screening, we have papers that scope the implementation and consequences of powered mobility over time; and we have used these, as well as the overall logic model of linked outcomes from review 1, as a starting point for understanding the potential long-term consequences of independent mobility resulting from powered mobility.

Chapter 6 Economic analysis: development of tariff of costs for paediatric powered mobility and a budget impact analysis for increased powered mobility provision for very young children

This chapter reports on a budget impact analysis to estimate the costs associated with different scenarios of paediatric powered mobility provision in the UK. As part of this analysis, a tariff of costs associated with paediatric powered mobility provision was developed.

The original objectives of the economic analysis were the development of:

- cost tariffs of NHS and non-NHS costs for powered mobility interventions (i.e. equipment, training and support, and any other components) for children with mobility limitations using a multiperspective disaggregated cost–consequence framework
- an economic model to facilitate a comparison of the relative cost-effectiveness of powered mobility equipment for very young children (< 5 years), compared with standard NHS practice (≥ 5 years).

After the completion of data extraction in review 1, it became apparent that there was very limited conclusive quantitative effectiveness evidence and no cost-effectiveness evidence. Hence, there were insufficient published data to allow a robust synthesis of cost-effectiveness evidence and the subsequent development of an economic model. In addition, no further relevant health economic or cost-effectiveness evidence was identified from further targeted searching.

As an alternative to the economic modelling of cost-effectiveness, we focused on costs and modelled different scenarios of providing increased access to powered mobility for children aged < 5 years with mobility limitations. We developed three hypothetical scenarios of service provision mapped on to the intervention elements outlined in the refined logic model. We aimed to illustrate the costs of early powered mobility, and the potential budget impact of increased powered mobility provision for very young children.

For the budget impact analysis, we established the costs of current provision of powered mobility to very young children (i.e. the base case), and the impact of making such provision available to all children who could potentially benefit. Provision to all by the NHS would inevitably lead to increased costs, due to a number of factors, as highlighted in the assumptions below; however, this increased cost should be considered in the light of the potential benefits to the children, as detailed in the syntheses, and additional cost implications for other services in the NHS. The conduct and reporting of the budget impact analysis follows the International Society for Pharmacoeconomics and Outcomes Research's good-practice guidance.[135]

Design and methods

The collection of primary economic data was not within the scope of this evidence synthesis project. To generate cost data, we liaised with a number of different organisations and individuals both within and beyond our project advisory group, including NHS Posture and Mobility Services; the National Wheelchair Managers Forum; charitable organisations such as Whizz-Kidz, Designability and the Medical Engineering Resource Unit (MERU) of Queen Elizabeth's Foundation for Disabled People; and various wheelchair manufacturers.

Data were also obtained from publicly available sources and publications. UK government data sets and related websites [e.g. Office for National Statistics (ONS), Department for Work and Pensions, Motability] were consulted to inform population calculations, allowances and grants available to people with disabilities and their carers.[136–138] NHS data sets were used to inform numbers of users and input to costings.[18,139–142] Published reference sources, published research and a freedom-of-information request were used to further inform aspects of the powered mobility costs, including staffing and equipment, and for costings of local authority spend on housing adaptations.

The studies included in the systematic review were screened for any cost or resource use information that could inform the analysis. Further targeted searching was carried out in an attempt to locate economic and cost-effectiveness data using the terms 'children' and 'condition' and an economic evaluation filter, whereby 'condition' referred to a list of conditions known to restrict children's mobility, and the economic evaluation filter was the narrow filter from the Canadian Agency for Drugs and Technologies in Health.[143] No further relevant economic or cost-effectiveness evidence was found from this targeted search, for either very young or older children.

In addition, detailed information on costs and resources used in the provision of powered mobility and training of children accessing assisted mobility options was obtained from personal communications with a number of NHS providers and third-sector organisations, including members of the project advisory group. [Advisory group personal communication: Amanda Allard, Council for Disabled Children; Rae Baines, Designability; Sara Crombie, Sussex Community NHS Foundation Trust; James C (Cole) Galloway, University of Delaware; Simon Halsey, TinyTrax; Susan Hillman, Newcastle upon Tyne Hospitals NHS Foundation Trust; and Krys Jarvis, Shropshire Community Health NHS Trust. Other personal communication: Ruth Everard, DragonMobility Ltd (Cambridge, UK); Roy Wild and colleagues, Go Kids Go!; Invacare Ltd (Bridgend, UK); Paula Jackson, Samantha Sterling and colleagues, Leeds Wheelchair Centre; Press and Public Relations Department, Motability UK; and Nicky Ellis, North East Essex Wheelchair Service. All personal communication took place in 2019.] Personal experiences of the pathway to obtaining their child's assisted mobility interventions were obtained from telephone discussions with the parent members of the project advisory group. These discussions focused on what the parents had to do to get powered mobility (e.g. appointments, travel, communication, out-of-pocket expenses), so that the costs could be estimated.

Data were obtained for 2018/19 whenever possible. We originally planned to inflate any earlier cost data not covered by recent publications using the Bank of England inflation calculator;[144] however, this proved unnecessary as we did not need to inflate any cost data. All of the relevant cost data were synthesised into a tariff of NHS and non-NHS costs relating to paediatric powered mobility provision, which was subsequently used to inform the budget impact analysis (see *Report Supplementary Material 2* for the budget impact analysis model).

Because the literature did not provide any data on the long-term impacts of powered mobility, a long time horizon could not be used. The calculations presented therefore relate only to the cost for very young children. From communication with various wheelchair services, we assume that wheelchairs are often refurbished and used by multiple patients over the life of the device; thus, it was important to adjust costs accordingly. We therefore assumed that a powered wheelchair or starter powered mobility device for a child would be useable for 5 years, and used by two consecutive children during that time.

It is anticipated that the budget impact analysis will be most relevant to the UK NHS setting, and, owing to the availability of data sets, specifically the NHS in England. The initial approach was to take a broader societal perspective; thus, cost implications for social care providers and for the families of children requiring powered mobility are presented when available, or the expected impact of increased provision is discussed in general terms.

Patient population

For the budget impact analysis, the target population was assumed to be all children aged < 5 years with a mobility problem sufficient for referral to NHS Wheelchair or Posture and Mobility Services. In current practice, some children who could benefit from powered mobility do not receive it, as they do not meet the criteria for provision. The aim of the budget impact analysis was to examine hypothetical scenarios in which more children are referred and more children receive powered mobility.

Medical diagnoses alone cannot be used to adequately estimate a child's capacity for movement; therefore, underlying diagnoses, conditions and diseases were not used to define the patient population. Rather, the anticipated aim was to explore paediatric powered mobility provision from a service level. Furthermore, from the systematic review, insufficient evidence was identified to support separate economic analyses for individual diagnoses. We therefore focused more generally on the provision of powered mobility to very young children. Likewise, there was very little long-term evidence to allow evaluation over time.

There is no national data set on provision of mobility equipment by age; therefore, we could not easily determine the exact number of children (across all ages) who currently receive powered mobility. Estimations of the total current population provided with powered mobility, and of the total population of very young children who could potentially benefit from powered mobility, were therefore based on available data from the NHS and ONS.

The quarterly National Wheelchair Data Collection requests top-line data from each Clinical Commissioning Group (CCG) in England, including the number of adults and children registered with and referred to wheelchair services. In the financial year 2018/19, at least 60,000 children aged up to 18 years were registered with wheelchair services.[18,139–141] This is potentially an underestimate, as the data for a number of CCGs are not presented. According to ONS population data for England, approximately 24% of children aged 1–17 years were aged 1–4 years;[138] applying this to the NHS data suggests that some 14,400 children aged < 5 years are currently registered with wheelchair services.

The national data collection reports 9200 new referrals of children aged 0–17 years to wheelchair services and up to 23,900 re-referrals annually. It is likely that children aged < 5 years will account for a disproportionately large number of new referrals, given that many mobility issues associated with conditions present from birth will be first noticed in this time. Anecdotal evidence from discussion with expert advisors suggests that the figure is about 80% of child referrals, suggesting that around 7300 children aged < 5 years are referred per year. Data were reported from only 182 of the 195 CCGs (93%), so it is possible that up to 7900 children are being referred nationally, which we have used as a maximum value in our calculations.

According to the NHS reference costs, of the 17,299 wheelchairs issued to children aged 0–18 years in 2017/18, 3591 were powered wheelchairs, accounting for 20.8% of wheelchairs issued.[142] Applying the proportion of children aged < 5 years to those aged < 18 years from national statistics, as noted above (24%), would suggest that almost 900 powered wheelchairs were supplied to this age group; this is likely to be an overestimate given the restrictions noted. Personal communication with a small number of individual NHS services and with manufacturers suggests that, on average, annual provision of powered mobility for very young children is likely to be in single figures per service (Susan Hillman; Krys Jarvis; Paula Jackson, Samantha Sterlin and colleagues; Nicky Ellis; Simon Halsey; and Ruth Everard, personal communication). Assuming that each of the 195 CCGs supplies around two very young children with a powered mobility intervention each year, this would put the figure at somewhere closer to 400.

In addition, data from the suppliers of Wizzybug[145] and Bugzi[146] indicate that around 200 starter powered mobility devices were loaned to children aged ≤ 4 years in 2018. We also know that a small number of families purchase powered mobility equipment privately for their very young children.

There is no way to accurately calculate how many families are doing so, but we estimate that 25 families obtain powered mobility through private purchase each year. Thus, the base-case assumption is that only 625 children aged < 5 years are receiving some form of powered mobility through the NHS or elsewhere.

The calculations here are, necessarily, based on assumptions, but they do suggest that the number of children who could potentially benefit from some form of powered mobility provision before the age of 5 years is, conservatively, at least double that of the current provision; however, realistically, this could be as high as three or four times the current provision level.

Powered mobility provision: current practice

Although powered mobility provision is not always explicitly restricted by age, very young children often fail to meet the necessary criteria and are thus ineligible by default. Individual protocols for provision of powered mobility vary from service to service, but assessment of suitability is usually influenced by considerations of ability, safety in use, supervisory elements and a child's environment. An NHS Wheelchair Service powered mobility provision process flow chart can be seen in *Appendix 11*, *Figure 9*.

There are some differences between provision for very young children and older children. Very young children who currently use powered mobility devices are likely to be from a limited or self-selecting group (i.e. their parents sought out powered mobility or they happened to live in an area where powered mobility was an option offered to them through the NHS), as there is not yet universal provision of powered mobility for children aged < 5 years. Conversely, older children are able to access powered mobility as part of routine NHS practice. Given the limitations in accessing such provision for the very young, it is possible that those very young children who are currently in receipt of a powered mobility are not representative of the wider population of very young children who could potentially benefit from such interventions.

In most cases, budgetary constraints mean that only one mobility aid is provided to each child by the NHS. As very young children are usually perceived to require a specialised buggy or manual/assistant-propelled wheelchair more urgently, services are commonly financially unable to support powered mobility for very young children. A number of third-sector organisations provide financial assistance to families seeking powered mobility, and families may be directed, or identify themselves, to such organisations, thus shifting cost and resource to the third sector. Alternatively, the NHS voucher scheme allows families to obtain a voucher to the value of the equipment prescribed by the NHS, in order to top up with other funds for another item. This is being superseded by the introduction of Personal Wheelchair Budgets, as part of the personalised health budgets, aiming to give people with long-term health conditions and disabilities more choice and control over the money spent on meeting their health and well-being needs.[147] A small number of NHS services work in partnership with the third sector to offer enhanced access to powered mobility.

Intervention mix

Aside from the actual device, powered mobility interventions also include referral, assessment, fitting, training, repair and review. The following aspects were considered in the development of the tariff of costs and the budget impact analysis: the cost of the mobility equipment itself; the accessories/modifications required; resources used in repair and maintenance; the cost of any training delivered; adaptations to the home, transport and school environment; and any service staff time or other human resource required.

At present, a significant amount of provision of equipment and training is carried out by the third sector. These costs are also discussed, with a view to costing the impact on NHS or other central resources should they take on a more comprehensive approach to the provision of powered mobility for very young children.

Items for which costs were not anticipated to be affected by the type of equipment provided are also discussed.

Uncertainty analyses

The findings from the evidence review and the lack of detailed data available on the provision of wheelchairs means that there is a high level of structural uncertainty in the costing analysis presented here on current and projected provision of powered mobility to very young children. We attempted to account for this by including broad minimum/maximum cost ranges. Further investigation into the resources used in the provision of mobility equipment to this age group and the long-term implications are needed to make a more robust model. The interactive model underlying the budget impact analysis is presented in *Report Supplementary Material 2*.

Tariff of costs for children's powered mobility

All relevant costs are summarised in the tariff of costs, presented in *Appendix 12*, *Tables 48–50*. The data, estimates and assumptions underpinning the cost estimates are presented in the following sections for each cost category, and the cost ranges used in the analysis are stated.

Powered mobility equipment

The systematic review and discussions with the project advisory group identified a number of ways in which powered mobility devices can be defined (see *Table 5* for further information). For the purpose of this economic analysis, we focused on interventions that are currently supplied by the NHS (i.e. starter powered mobility devices and powered wheelchairs).

In addition, we included adapted ride-on toys in our analyses. Such devices are in use outside the UK, notably in the USA and Canada, and were the subject of a relatively large number of the studies identified in review 1. Although they represent a promising, low-cost approach to powered mobility provision, they are currently considered to be outside the remit of NHS practice as they do not meet the classification for medical devices. The adaptation of ride-on toys fitted with harnesses, supportive seating and/or controls through schemes such as GoBabyGo[56,57] can allow very young children with mobility limitations to have relatively inexpensive experiences of independent mobility. These devices could be a future route for NHS powered mobility provision, and thus have been included in a sensitivity analysis.

Other options described in the literature have not been considered to be relevant to the NHS in the immediate future, and so are not covered in the scenario analyses presented here. This includes models and robots designed for specific research, the manufacture of which would need to be scaled up and undergo medical device assessment before use could be routinely endorsed by the NHS.

Powered wheelchairs

The price of powered wheelchairs varies widely according the features required to address individual clinical need. In addition, NHS and other providers serving the NHS will be offered discounted prices that are lower than the publicly available list price. Although, in general, powered wheelchairs are more expensive than manual wheelchairs or buggies, the actual prices paid and the relative differential between powered and manual equipment varies widely in the limited national data available; therefore, it is possible to suggest only an approximate average cost.

The NHS reference costs for children's 'high need' powered wheelchairs increased over a 5-year period from £377 in 2012/14, to £1760 in 2016/17. The most recent published figures for 2017/18 state a unit cost of £656 for the basic cost of a 'high need' powered wheelchair for children. This is more than double the cost of 'low need' (£266) and > 60% higher than 'medium need' (£394), but only slightly higher than the cost of a 'high need' manual wheelchair (£646). In addition, 'specialist modification costs without supply' are stated to be £139.[142]

The *Unit Costs of Health and Social Care 2018*[148] does not distinguish between provision for adults and children, but cites a capital cost of £1528 for a powered wheelchair, annuitised to £338 over 5 years. This is more than five times the cost for a self- or attendant-propelled manual wheelchair. Combined with maintenance revenue costs of £129, the unit cost rises to £467 per annum over 5 years. The authors of these unit costs[148] cite one commercial site where costs range from £100 to £1300 for self- or attendant-propelled manual wheelchairs, and from £1000 to £5000 for powered wheelchairs.

From discussions with contacts within the NHS and the project advisory group (predominantly service providers/managers, service commissioners, commercial directors and representatives of national charitable organisations), and from reviewing the equipment cited in publications identified in the evidence review, we ascertained that the prices for powered wheelchairs for very young children are higher, ranging from £1800 to £8500. Based on the cost of chairs cited by NHS contacts and manufacturers' list prices, our best estimate for the average cost of a powered wheelchair in this age range is £3939 (range £1800–8500). We assumed that these devices would be used by two children over the life of the chair; the cost per child is thus £1970 (range £900–4250). This is similar to the figures presented in the report *Developing a Wheelchair Tariff Pilot Programme*.[149]

Starter powered mobility devices

Starter powered mobility devices, such as the Wizzybug[145] and Bugzi,[146] are generally aimed at children up to the age of 5 years (or weight limit of 25 kg). Other items aimed at this younger age group offer the potential for continued use after the age of 5 years, such as the TinyTrax, with a 'grow with me' design, and the SnapDragon (Dragonmobility Ltd).[150]

These devices are not generally funded directly by the NHS, and are usually provided by loan through the third sector, either directly from the organisation or referred to by (or in collaboration) with therapists in the NHS. Families often obtain funding by application to other third-sector organisations for support, or fund the loan themselves. Manufacturers and other third-sector sites provide links to potential sources of funding. Families may privately fund the purchase entirely, although this is not thought to happen regularly.

Some professionals actively direct families to loan schemes or make them available to children through their own service. The current refundable deposit fees for Bugzi and the Wizzybug loans are between £100 and £200. The devices are loaned until the child no longer requires them, and are then returned for refurbishment for future loan. Capital costs of the items are between £3500 and £5000. Costs of provision and maintenance are often met by the supplying charity; however, in some cases, there will be extra associated costs, such as transport to the assessment/for collection and for maintenance. Based on these costs, our best estimate for the average cost of a starter powered mobility device is £4250 (range £3500–5000). Assuming that these devices would be used by two children over the life of the device, the cost per child is £2125 (range £1750–2500).

Ride-on powered toys

A number of researchers have explored building equipment to give very young children some experience of mobility through self-builds, using carts, robots and adaptations of ride-on car toys. The materials costs are relatively low in comparison with commercially available powered mobility equipment; however, the items are often bespoke for the child, so the amount of engineer resource may vary significantly according to need and the complexity of the build. The GoBabyGo scheme utilises students' science, technology, engineering and mathematics (STEM) projects and estimates costs of the toy and adaptations as US$500.[56] Our best estimate for the average cost of an adapted ride-on powered toy is, therefore, £410 (range £310–510), based on the assumption that these devices would be useable by only one child, and the similar provision of engineering resource, using STEM students or voluntary resource.

Staff time and activities

The NHS reference costs for 2017/18[142] include separate unit costs for a number of activities relevant to the provision and maintenance of wheelchairs to children up to the age of 18 years, primarily

associated with staff costs (i.e. physiotherapists, occupational therapists, engineers and administrative staff). Unit costs are presented for assessment (unit cost £368), modification/customisation (unit cost £139), review (unit cost £232) and repair/maintenance (unit cost £214). In the budget impact analysis, these have been combined into two costs: one for assessment, modification and provision and one for review, repair and maintenance. Costs for assessment, modification and provision are one-off costs, occurring only once for each child, whereas costs for review, repair and maintenance occur on an annual basis, assuming that reviews and subsequent maintenance are carried out annually. Therefore, our best estimate of the additional staff cost to provide a powered wheelchair is £507 per child (range £368–936). Our best estimate of the additional cost to review and maintain a powered wheelchair is £446 per year, and, assuming each child receives three reviews/maintenances during their use of the device, this equates to a best estimate of £1338 (range £1017–1365) per child.

The staff costs of assessment, provision, review and maintenance for starter powered mobility devices, such as Wizzybug and Bugzi, are typically met by the provider organisation, and are thus assumed to be included as overheads in the cost of the device. Therefore, for the purpose of this analysis, we have not included separate staff costs for third-sector staff activities.

Accessories, modification and customisation

The level of need for accessories and modifications varies widely according to a child's needs and clinical circumstances. Some users will require additional items and adaptations such as seating and other support, seatbelts or harnesses and bags or carriers for other essential medical equipment. These may be relatively standard or require bespoke manufacture for an individual user.

In terms of modification and customisation, the national schedule of reference costs for wheelchair services includes just over 1000 units of activity for children, described as 'Equipment, Specialist Modification Without Supply' in 2017–18, at a unit cost of £139. Over 4500 units of activity were described as 'Specialised Complex Wheelchair Services', at a unit cost of £429. Neither of these was categorised further.[142]

The NHS reference costs assume a unit cost of £143 for a review of substantial accessories.[142] Manufacturers may include the cost of harnesses, certain seating, headrests, armrests, etc., in their list price, but there may be a need for bespoke specialised supportive seating as well. It has been assumed that these would be similar for a powered and a non-powered mobility device. Other additional costs associated with powered mobility equipment include attendant or dual controls, plus additional batteries and charging equipment, both of which may run into several hundreds of pounds.

Owing to the large variance in children's needs for accessories, modification and customisation, it is difficult to apply a single cost for these aspects of the intervention. Based on previously reported data on the proportion of paediatric wheelchair intervention costs associated with accessories, modification and customisation,[151] we have used a multiplier rate of 23% to the base cost of powered mobility devices and 6% to the base cost of starter powered mobility devices to predict the cost of accessories, modification and customisation (excluding staff costs).

Training

The studies identified in the systematic review were reviewed for information on any training provided to children aged < 5 years. There was a wide variation in the duration of training interventions and settings. The number of attendances and total duration of interventions delivered in this way also varied, with some lasting several months.[74,117] Several studies describe provision of an initial single session or guidance provided to the caregiver, for example Evans and Baines's[62] description of the training provided to families on receipt of the Wizzybug and training provided by Mockler *et al.*[111] to parents of users of powered wheelchairs, in a manner presumed similar to the NHS. There was no consensus on the optimum duration/number of training sessions.

Provision of training for use of powered mobility varied widely among the NHS services contacted. Some level of training will be achieved through any trial undertaken as part of the assessment of suitability of provision of powered mobility, but this has not been costed as such for the purposes of this section of the report, to avoid double-counting. Training is also delivered by the therapists at a clinic, at home or in school, usually at the point where the equipment is provided, which may be at the provider site or at the user's home or school. It is usually limited to showing how the controls work and observing the chair in use, lasting up to 1 hour, but could take much longer for children with cognitive impairments. Again, this has not been costed separately to avoid double-counting. Provision of training for use of the starter powered mobility devices is limited to handover, during which the charity or the partner organisation's therapist will provide caregivers with bespoke advice on learning through play.[62] Thus, training that we believe to be part of assessment/provision has not been costed separately.

More formal training sessions are provided by a number of third-sector organisations; for example, the NHS web page *How to Care for a Disabled Child*[152] specifically refers to Whizz-Kidz[153] and Go Kids Go![154] as providing free training services. Go Kids Go! provides workshops aimed at children aged > 2 years using manual and/or powered wheelchairs. Family members may also attend and some workshops are aimed at school groups, including non-users of wheelchairs. In 2017, training was delivered to almost 300 children with disabilities and > 2000 beneficiaries in total, including the children themselves, family members, school attendees and health and education professionals.[155] This is one area for which the costs of powered mobility provision may be less than for a non-powered wheelchair; without balancing training (users of self-propelled manual chairs require training on balancing skills to manage uneven surfaces, kerbs etc.; powered chairs are more stable and so this element of training is not required), training sessions may be reduced from 5 to 3 hours. The overall cost of running a workshop is in the region of £2000, requiring trained professionals to run the session, and often additional support from technicians and volunteer wheelchair mentors. According to Roy Wild of Go Kids Go! (personal communication), the cost per user is around £450 (estimated range £350–550), including overheads; thus, we have used this as our unit cost for training. We have also assumed that 10% of powered mobility users access this training.

Adaptations to housing, community facilities and transport

Powered wheelchairs are generally larger and heavier than manual wheelchairs; therefore, greater and/or further adaptations to housing, community facilities and transport may be required. For example, doorway widths may need to be further adjusted. In 2003, work from Canada surveying users of powered wheelchairs found that 50% experienced barriers to use in the house, 62% found physical barriers in the workplace or at school and 56% experienced barriers in community buildings.[132] Although half of those surveyed had received a wheelchair before the age of 5 years, no information is presented detailing when these issues first arose. As it is probable that, in recent years, more housing and community facilities are being designed to be accessible, information on the costs of modifications are included in the analysis.

Housing

Families with a disabled child may be able to access funding from their local authority for up to £30,000 in England to adapt the home.[147] The mean grant provided is £7500 (this value includes adults, as adaptations for wheelchair use are standard and unrelated to age of user).[156] The number of families accessing these grants is unknown, but is likely to be a small proportion; we have therefore assumed that 10% of children would receive funding for housing modifications before the age of 5 years, factoring in that some homes would not need to be adapted.

Costs calculated for relevant housing modifications were taken from the Personal Social Services Research Unit's *Unit Costs of Health and Social Care 2018*.[148] Assuming that an entrance requires a ramp (at a cost of £906 per ramp), a doorway widened (at a cost of £667 per door) and path (at a cost of £153 per path) installed, and that each child would require two entrances to be adapted, the total cost equates to £3452 (range £1726–7500) per child, which we have used for our unit cost.

Community facilities

Adaptations may be required to community buildings likely to be visited by children who might benefit from powered mobility outside the home, for example schools, recreation centres, community centres and places of worship. No specific information was found about the associated costs of community adaptation in the systematic review. Although it is assumed that the costs of providing adaptations to accommodate a powered mobility device in such spaces would be the same as for housing, as most new community buildings are already built with accessibility in mind, and many older buildings will have adaptations already in place. It is anticipated that the number of new adaptations specifically for a child using powered mobility would be small; therefore, these costs are not included in the analysis.

Transport

There are no current data on the proportion of families requiring different or adapted vehicles because of their child's disability, nor of the relative requirement for this based on use of a powered versus a manual mobility device. However, transport is recognised as causing issues throughout the review data. In the Canadian survey,[132] > 70% of respondents cited difficulty transporting their powered wheelchair. In 2003, the organisation Whizz-Kidz published findings from a postal survey[106] among families of children aged < 7 years who had been provided with powered wheelchairs; 61% said that they transported the child in the car, using a four-point strap and/or ratchet clamps. The Motability Scheme in the UK allows parents or carers of children aged ≥ 3 years to use their mobility allowance to lease a car or wheelchair-accessible vehicle.[137] Data obtained from personal communication with Motability UK (Press and Public Relations Department, Motability UK, 2019) indicate that, in the financial year 2018/19, 120 grants for these were made in relation to children aged < 5 years, which is < 10% of the grants awarded to all children aged < 18 years. This might be expected to increase should a greater number of this age group be given access to powered mobility options suitable for use outside the home.

Motability grant values averaged £2706 in 2018, so this has been used for our best estimate (range £2435–2977).[157] We have assumed that 10% of children will receive Motability grants. Families may need to top up this funding, but the exact levels involved have not been determined for this report. Similarly, we acknowledge that there will be additional travel and associated increased costs, such as fuel and depreciation of vehicles, for travel to appointments, training, etc., but insufficient data are available to quantify this.

In terms of transport to school, local authorities are responsible for the provision of free transport in appropriate circumstances, including to children with disabilities that affect their ability to walk. Legally, transport is required to be provided for eligible children only from the age of compulsory education (5 years),[158] although many authorities provide transport for eligible children from the commencement of the school year in which the child attains the age of 5 years and starts full-time education, which is more commonly at age 4 years. Provision of powered mobility suitable for indoor and outdoor use to very young children, as opposed to waiting until they reach the age of 5 years, may increase the need for provision by an extra year per child, but, because of the lack of corroborating data, we have not included this cost in the analysis.

Human resource

The human resource costs of powered mobility interventions are significant, as already highlighted by the staff costs (see *Staff time and activities*) and cost of home adaptations (see *Housing*).[148,159] As noted above, for assessments, provision, review and maintenance, we have used the costs suggested in the NHS reference costs, which have incorporated relevant staff resource.

The potential impact on wider society in terms of the caregiver and the wider family, and on those involved in provision of early-years schooling, has been considered; minimal evidence of reduced need for support in school was found in the literature or in consultation with our advisors; therefore, human resource costs associated with education have not been included.

Likewise, there was no evidence on the impact of powered mobility provision on parent/family productivity; therefore, these costs have also been excluded from the analysis. Although we appreciate that, in reality, there are likely to be financial implications for families, there are insufficient data to accurately calculate this at present.

Areas of no impact

There was no evidence of impact on a child's medical diagnosis; therefore, we have not assumed any differences in need for, or type of, medical interventions including medication or surgery, nor of any staff or other resources related to these. Although changes in children's behaviour/independence levels may affect some other areas with cost implications, it was not possible to determine the probable impact from the literature; the evidence does not allow us to quantify by how much or in what time frame any benefits may be realised.

Defining powered mobility provision scenarios for the budget impact analysis

To estimate the change in costs associated with increased powered mobility provision, a base-case (i.e. current provision) scenario was defined and a further three hypothetical scenarios were developed (see *Box 1*). The costs associated with individual provision do not vary between scenarios because the budget impact analysis is based on changes to the number of referrals and powered mobility devices provided. The assumptions regarding population and resources are presented in the next section. The analysis model, based on our estimations of minimum, best-estimate and maximum levels for population, equipment and resources required, is presented in *Report Supplementary Material 2*. In the analyses, it has been assumed that all referred children receiving mobility equipment from NHS services will receive a buggy or assisted/manual wheelchair and that the provision of powered mobility will be an additional cost.

Base-case assumptions

Population

- A total of 7300 children aged < 5 years are referred to NHS Wheelchair Services.
  - Of these, 400 are assessed for a powered mobility device and receive it.
- An additional 225 children receive a starter powered mobility device from the third sector or privately outside NHS services.

Mobility equipment

- Powered mobility device costs are based on the assumption that each device will last for 5 years and be used by two children during that time, assuming that each device is refurbished and then reused once (refurbishment costs are included in repair/maintenance costs).
- NHS provision is based on current NHS practice. Specific powered mobility device models are likely to vary, and may include some starter powered mobility devices: best estimate £3939 per device (range £1800–8500), equating to a cost per child of £1970 (range £900–4250).
- Third-sector provision is based on reported costs from manufacturers. Specific devices include Wizzybug[145] and Bugzi:[146] best estimate £4250 per device (range £3500–5000), equating to a cost per child of £2125 (range £1750–2500).
- Powered wheelchair costs and starter powered mobility device costs are multiplied by 23% and 6%, respectively, for each child, to account for customisation and modification.

Resources used in assessment, provision, handover and maintenance of powered mobility

- One-off staff costs associated with the assessment, provision and customisation of powered mobility are included in the analysis: £507 (range £368–936) per child.
- It is assumed that each child receives three reviews/maintenances during their use of the device: £1338 (range £1017–1365) per child, with lower maintenance frequency for less complex needs.
- For third-sector provision, it is assumed that all costs associated with assessment, provision, review and maintenance are included as overheads in the cost of each device.

Training

- Families of children requiring training for all wheelchair types are directed to further wheelchair training, provided by third-sector organisations such as Go Kids Go! or Whizz-Kidz, with 10% of children attending this training: £450 per child (range £350–550).

Housing and transport

- It is assumed that 10% of families receive adaptations to the home associated with powered mobility provision: £3452 per child receiving adaptation (range £1726–7500).
- It is assumed that 10% of families apply for a Motability grant to adapt their car for a powered mobility device: £2706 per child receiving adaptation (range £2435–2977).

Alternative service scenario assumptions

The three alternative service scenarios used to estimate the costs associated with increased powered mobility provision for very young children are defined in *Box 1*.

BOX 1 Assumptions used in the budget impact analysis alternative service scenarios

Service scenario A

Increased access to powered mobility

- The number of children aged < 5 years referred to NHS Wheelchair Services remains unchanged ($n = 7300$); however, all 7300 children are offered assessment for an appropriate powered mobility option. Although the volume of assessments increases, there are no changes to NHS resources used in referral, handover, review or maintenance for each child.
- As a result of increased assessments, more children are offered powered mobility – in this scenario we have assumed that the number of children who receive powered mobility doubles, to 800. The types of interventions offered by the NHS do not change; thus, the cost of equipment per child remains the same.
- Third-sector/private provision also increases, as more children are assessed for powered mobility by the NHS, but then seek such equipment elsewhere, either because of refusal or unmet need. For uniformity, third-sector/private provision also doubles, to 450.
- Although this scenario would have implications on staff numbers, training and clinic space, we have assumed that current NHS and third-sector provision of equipment, training and staff resource can expand to meet demand.

BOX 1 Assumptions used in the budget impact analysis alternative service scenarios (*continued*)

Intervention scenario B

Increased access and demand for powered mobility

- The number of children aged < 5 years referred to NHS Wheelchair Services increases by 10%, to 8000. All children are still offered a powered mobility assessment. Although the volume of assessments increases, there are no changes to NHS resources used in referral, handover, review or maintenance for each child.
- The number of children who receive powered mobility consequently increases by 10%, to 880. The types of interventions offered by the NHS do not change; thus, the cost of equipment per child remains the same.
- Third-sector provision also increases, as more children are assessed for powered mobility but then seek such equipment elsewhere because of refusal or unmet need. For uniformity, third-sector provision also increases by 10%, to 495.

Intervention scenario C

Increased access and demand for powered mobility, and third-sector provision transferred to NHS/other state organisations

- As scenario B, but the NHS takes on the costs currently assumed by the third sector; therefore, the number of very young children receiving powered mobility through the NHS increases to 1375.
- The proportion of children receiving powered wheelchairs and starter powered mobility devices remains the same.
- The NHS resource costs are unchanged from scenario B, assuming that the third-sector maintenance costs are included in the transferred provision.
- The NHS also takes on the cost of formally training each child to use powered mobility: £450 per child, with 50% of children accessing training.

Results: budget impact analysis

The data presented in the tariff of costs in *Appendix 12* and the assumptions stated in *Box 1* were used to estimate the current cost of provision of powered mobility options by the NHS, additional costs due to housing and vehicle adaptation, and the cost of provision of equipment and training by the third sector. See *Report Supplementary Material 2* for the budget impact analysis model. *Table 38* summarises the findings.

Based on the results from the budget impact analysis, we predict that the NHS CCG spend on the provision of powered mobility to very young children is currently around £1.9M annually, which is < 2% of the overall reported CCG spend on wheelchair services. This is based on an assumption that 400 very young children are provided with powered mobility each year. Based on our analysis, the third sector spends > £0.5M on powered mobility provision to a further 225 children, and provision of some training in this age group. Although it appears that the costs of provision per child are lower for the third sector than for the NHS, this is largely driven by the lower costs of the equipment provided, as we have assumed that the NHS currently provides powered wheelchairs with additional servicing costs, whereas we have assumed that the third sector largely provides starter mobility devices for which these costs are included. A further £0.4M is spent on adaptations to support powered mobility through funding from public services and the third sector.

TABLE 38 Summary of total costs associated with early powered mobility provision and results from the budget impact analysis of alternative service scenarios

	NHS provision of powered mobility (£)	Adaptations to home and/or vehicle[a] (£)	Third-sector provision of powered mobility and training[b] (£)	Overall combined cost	NHS spend as % of reported wheelchair service spend[c]	NHS spend as % of estimated wheelchair service spend[d]
Estimated cost per child	4720	6200	2830			
Base case	1.89M	0.38M	0.56M	2.84M	1.75	1.46
Scenario A	3.78M	0.77M	1.13M	5.67M	3.50	2.93
Scenario B	4.15M	0.85M	1.24M	6.24M	3.85	3.22
Scenario C	5.64M	0.85M	N/A	6.49M	5.22	4.37

N/A, not applicable.
a It is assumed that 10% of families receive grant funding for housing and/or vehicle adaptations.
b In the base case and in scenarios A and B, it is assumed that 10% of children receive formal training; in scenario C, it is assumed that 50% of children receive formal training.
c The reported total spend by NHS England CCGs on wheelchair services in 2018/19 was £108M, based on the quarterly wheelchair data collection.[18,139–141]
d Estimated cost projected to all CCGs (£129M).

To estimate the cost of increasing supply and demand for powered mobility, we modelled hypothetical increases to powered mobility provision. In scenario A, the number of children provided with powered mobility was doubled in both NHS and third-sector provision, to illustrate the change in cost associated with a more open approach to early powered mobility provision, and based on current numbers of children referred for mobility equipment. The cost to NHS services increased to £3.8M, and the cost to the third sector increased to £1.1M.

In scenario B, we modelled a situation in which more children are also referred for powered mobility, as well as increased provision, increasing costs to £4.2M and £1.2M for NHS and third-sector providers, respectively. In the final scenario, scenario C, we developed a hypothetical situation whereby the NHS takes on all early powered mobility provision, and therefore covers all costs associated with third-sector provision. Although this is highly speculative, at present the third sector is relied on to fill the gap in early powered mobility provision, and, given the potential health and developmental benefits of early powered mobility, there is an argument that the NHS, or other centralised funding, should be responsible for supporting all provision. We therefore undertook scenario C to estimate the associated cost implications of shifting all costs for powered mobility provision to the NHS. The results indicated that NHS costs would increase to £5.6M (including an additional increase in standardised provision of powered mobility training).

Of the 195 CCGs covered by the National Wheelchair data collection, 131 reported annual spend on wheelchair services,[18,139–141] indicating a total spend of > £108M. Assuming that the mean spend for each CCG providing data can be assigned to those CCGs that did not, the total figure could be in the region of £129M. The results indicate that even if the NHS were to double provision of powered mobility for very young children, and to take on responsibility for all third-sector provision, the costs would remain relatively low, in relation to the overall budget for wheelchair services, at between 4.3% and 5.2% of reported CCG costs.

Factoring in all relevant public sector and third-sector costs, the cost of an early powered mobility intervention is likely to fall below £10,000 per child. This cost could be reduced through bulk purchasing, increased repair/maintenance and subsequent reuse of individual devices. In the

highest-cost scenario, the potential cost to the NHS exceeds £10M, but it is of note that this is based on the worst-case scenario for all variables, and is therefore unlikely.

Despite the speculative nature of this analysis, the results indicate that powered mobility provision for very young children could feasibly be increased without major increases to budget. Furthermore, the results could be used to inform budget allocation to support increased provision.

Outside the UK, particularly in North America, there is interest in provision of adapted ride-on toys to provide a powered mobility experience. Currently, we do not believe that access to this kind of intervention is being provided by the NHS, and have little evidence of bespoke adaptations being made outside this. However, if the NHS were to adopt a scheme like GoBabyGo in the USA, where student resource is used to adapt the vehicles, the costs are estimated to be in the region of £410 per vehicle. If every very young child with mobility needs referred to wheelchair services was offered access to such a device, the potential cost would be £3M per year (range £2.9M–3.2M). It is likely that this kind of intervention would not be suitable for all children because of their differing needs and abilities, which would reduce this cost. However, if the adaptations were to be taken on by the NHS, costs of engineer resource would need also to be taken into consideration.

In addition to the lack of conclusive data from the systematic review on the probable positive and negative influences of early powered mobility on costs, the nationally available NHS sources lack detail on the provision by age, in terms of both patient numbers and equipment costs. The scope of this project was not to undertake primary data collection for the purposes of an economic analysis. We have therefore used published NHS costs when available, supplemented by discussion with members of the project advisory group (specifically service providers/managers, service commissioners, commercial directors and representatives of national charitable organisations). Feedback suggests that the costs of equipment cited in the reference sources are likely to be underestimated, and thus the costs of service provision may also be inaccurate. However, although we have attempted to cost equipment more realistically, we have used NHS data on resource use, as we identified a wide variety of approaches used locally across CCGs and services contacted. These include the following:

- differences in protocols for provision of early powered mobility that affect access, even if not categorically setting an age threshold
- the number of CCGs supported by a wheelchair/posture and mobility service
- use of centralisation of some aspects, for example engineering across multiple services
- the level of contracting out to non-NHS providers
- the level of collaboration with third-sector providers
- the choice of powered mobility equipment provided and the variation in contract prices for equipment
- the type and level of professional and support staff involved at different stages of provision.

There were no robust economic data on the impact on users' families identified from the systematic review. In particular, there was no detail on the level of funding outside the NHS through top-ups to funding accessed by vouchers or personalised wheelchair budgets, or by third-sector grants. In addition, we know that individuals may fully fund the purchase of new or second-hand equipment, but the extent of this is unknown. Based on this, we acknowledge, but have not attempted to cost, this aspect.

We have not incorporated any costs associated with initial referral, which may increase from scenario B onwards. We are aware of significant staff and carer time and resource use to make a case for provision for exceptional cases, but the number is unknown; thus, we could not incorporate such cost in the analysis.

A further significant consideration is the general capacity for increasing the resource allocated to increased provision. Increased staff resource would require re-allocation and/or recruitment and training of additional staff. Our calculations have not considered any costs of new assessment equipment or new/extended buildings to accommodate increased clinics.

Scenario C makes a hypothetical transition from no collaboration with third sector to the NHS assuming all costs of provision by the third sector. However, in reality there is some collaboration now, which is likely to grow. We do not intend to imply that there is no role for the third sector in the future, only that the costs related to the provision of equipment should be covered elsewhere. For the purposes of this review, we have assumed that this is the NHS, but it could come from other central funds.

We did not attempt to make assumptions about future developments, which are likely to affect this field. It is likely that technological advances will be introduced, and therefore costs will change. In addition, the roll-out of personalised wheelchair budgets, replacing the current voucher scheme, may also affect the range of items provided and associated costs.

The awareness of and interest in the importance of early powered mobility is growing. Earlier provision of powered mobility is unlikely to change the number of children with mobility needs being referred to the NHS; however, the interaction with the service, the provision of powered mobility and associated need for adaptations, reviews and repairs will occur earlier in their lives, bringing the costs forward. The result may be that more children are referred earlier, and that more children meet the criteria for early powered mobility earlier.

We found that the most recent reference costs were far lower than the costs of powered wheelchairs reported by the CCGs we contacted, and we found a variation in the protocols and activities associated with the provision of early powered mobility. These issues were also noted in the report[149] on the work carried out by Deloitte (London, UK) in the development of a wheelchair tariff generally, not just for this specific group of users. Further work is needed to determine, in more detail, the extent and cost of provision of mobility equipment and the supporting services.

Chapter 7 Integrative synthesis: an integrated logic model to inform the future planning for, and evaluation of, the outcomes of powered mobility for children

The final resulting logic model (*Figure 8*) presents, in a single figure, the key hypotheses about powered mobility outcomes resulting from an overarching synthesis of the components of this work. The logic model provides a key set of powered mobility outcomes that those planning and commissioning powered mobility equipment may wish to consider. It also provides information about the direction of the outcomes and the overall evidence base, across different study designs and types, underpinning those outcomes. It provides a framework for future research and service evaluations of powered mobility outcome interventions, including a clear map of the current evidence gaps. The following section provides a brief, narrative overview of our overarching synthesis and logic model.

The identified evidence focused on two intervention elements: the powered mobility equipment and training for the child to learn to drive that equipment. There was strong evidence from a range of study designs, clinical populations, and ages of children to suggest that powered mobility equipment is generally a feasible and acceptable intervention. Evidence from qualitative studies further contextualised feasibility and acceptability, for example by exploring how parents of children with degenerative conditions could express the negative inevitability of their child's degenerative condition towards the need for powered mobility, which shaped their conceptualisation of acceptability. Likewise, some parents of very young children preferred ride-on toys to powered wheelchairs because of the former's resemblance to the types of toys a child would usually play with in young childhood; thus, they were not perceived to stigmatise their child in the same way as a wheelchair.

The evidence across studies further indicated that powered mobility equipment can have a positive impact on a child's movement and mobility, and that movement and mobility as an outcome consisted of two inter-related dimensions: (1) play-related movement, whereby a child was doing 'movement for movement's sake', and which included a range of age-appropriate and developmentally appropriate experiences, exploration and enjoyment of movement-based play and physical activities, and (2) destination-focused mobility, whereby a child moved to get from A to B for a purpose of doing something else at destination B. Although the specific play-related movement activities varied based on a child's age and developmental level, the core concept of movement for its own sake as an important powered mobility outcome was present across the age groups. The overall synthesis did not support a hypothesis that play-related movement is important only for younger children, or that its primary function is the learning of movement skills. There was some evidence to suggest that destination-focused movement may become increasingly important as children grow older and ascertain increasing control and independence over where they go, when and with whom.

Although there is no conclusive evidence of effectiveness, it is clear that powered mobility equipment is a good way to enable children to move around (for play and physical activity) and to get to places. When considering the outcomes of powered mobility, both of these (moving for play and moving to get to places) are important.

There was evidence that powered mobility training can enable children to learn to drive powered mobility equipment, but this evidence was inconsistent, in that training was not equally effective for all children (especially for children with cognitive impairments), and in that there were two contrasting ways to hypothesise the place of learning in powered mobility intervention outcomes. One was that

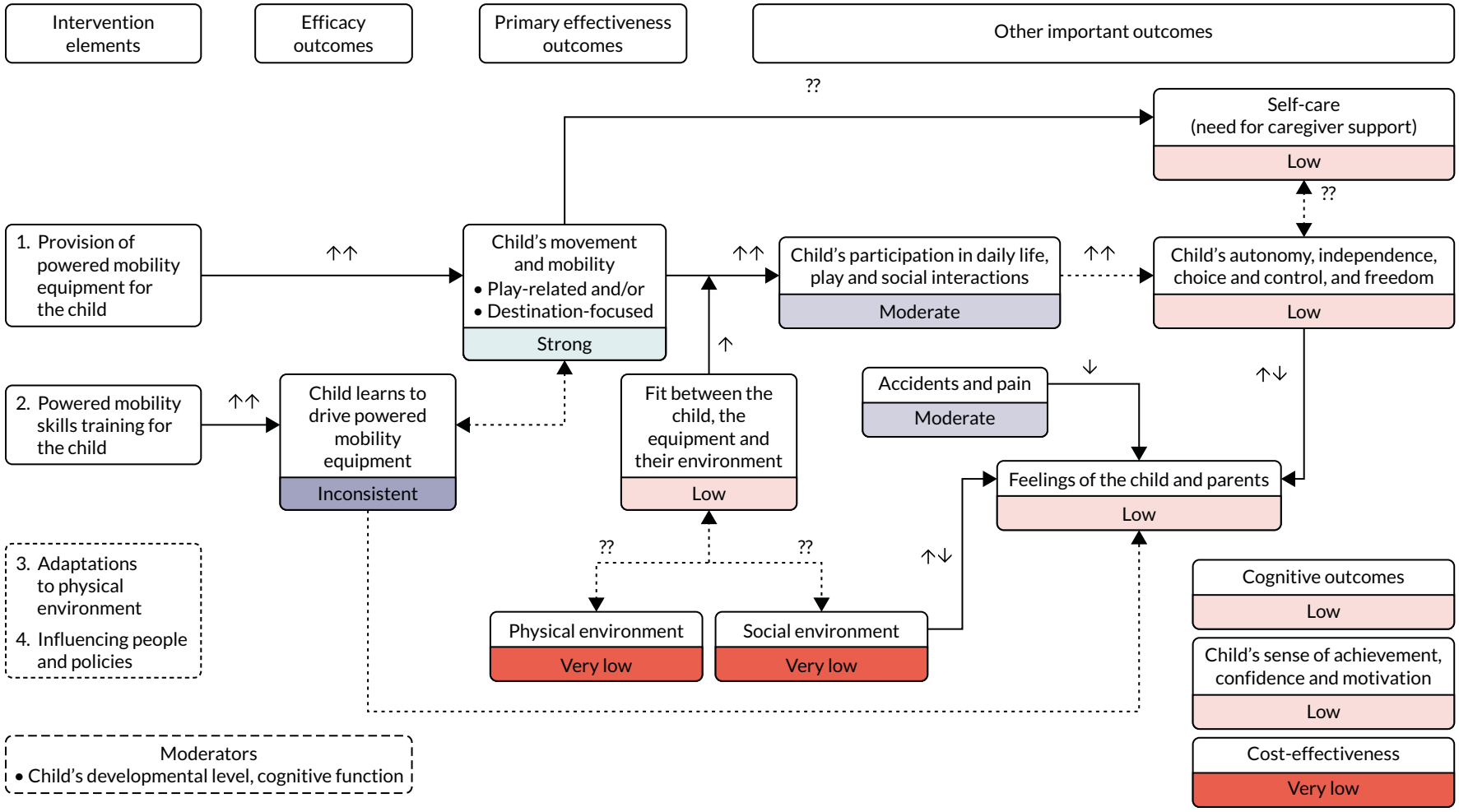

FIGURE 8 An integrated logic model to inform the future planning for, and evaluation of, the outcomes of powered mobility for children. Solid arrows linking concepts represent hypotheses that were developed based on consistent evidence across different study types. Dotted arrows linking concepts represent tentative hypotheses implied in selected studies but with a limited evidence base across study types. Arrows above the lines signify whether the hypothesised relationship is positive (arrows up), negative (arrows down), mixed (one arrow down and one up) or uncertain (a question mark). The stated level of support (inconsistent, very low, low, moderate or strong) for each concept refers to the overall range and depth of evidence across different types of studies for each concept.

learning to drive powered mobility equipment was a prerequisite for powered mobility use, for the movement and mobility outcomes, and for all other subsequent outcomes. The other was that learning to drive the equipment was the result, an outcome, of using powered mobility in movement and mobility. There was evidence to support both perspectives. There is little doubt that learning to use powered mobility equipment is a relevant outcome. However, how and when the learning can be enabled in the most cost-effective way remains a key question, and is a recommendation for future research.

Early introduction of powered mobility can facilitate children to develop powered mobility skills through playing and learning to use the powered mobility devices. Regardless of age, children need time and support to master powered mobility, and benefit when the device, environment and motivation of those around them are optimised. Powered mobility training need not be seen solely as a formal activity, as children benefit from simply using such devices and developing skill through experience.

Beyond movement and mobility, outcomes related to participation (including play and social interactions) and autonomy (including choice, control, freedom and independence) were consistently presented in the data as being highly valued. There was evidence to link participation outcomes to powered mobility, mainly from textual data, with quantitative outcome measurement lagging behind the narrative conceptualisation. Autonomy, as a more abstract term, remained more elusive. It was often described and illustrated through everyday movement and participation examples, but corresponding quantitative data were limited.

Outcomes related broadly to participation and autonomy are likely to be important; further research is needed to capture them meaningfully and to evaluate the effectiveness and cost-effectiveness on them. In health economics research, these types of outcomes are typically understood through the evaluation of health-related quality of life or capability, and, in turn, the relationship between incremental cost and incremental benefit can be evaluated to determine cost-effectiveness. For such young children, the use of standard health economics outcomes measures (such as the EuroQol-5 Dimensions) is likely to be difficult, as few are validated for this age group. Likewise, the variance in impairments, abilities and prognoses is likely to introduce confounding variables without tight control of the sampled population. Given the small number of children aged < 5 years who use or could benefit from using powered mobility, this poses great difficulty in the assessment of cost-effectiveness. One solution is to monetise all costs and benefits, and to use a long time horizon to evaluate impacts to public service expenditure over time, assuming that early provision of powered mobility has health and developmental benefits in the future. At present, there is essentially no evidence to support this analysis; thus, additional research is needed to identify a core set of outcomes that can be evaluated reliably to determine effectiveness and cost-effectiveness. The budget impact analysis demonstrated that, even with greatly increased provision, NHS costs for early powered mobility provision would still remain a small proportion of overall wheelchair service costs, but the relationship between these costs and children's outcomes is still unknown.

The issue of risk and safety in relation to early powered mobility has often been used as a barrier to acceptability and feasibility of earlier provision. This concern is not just expressed by wheelchair services, but also by parents, who may initially be reluctant to accept powered mobility. This reluctance can also be related to the symbolic nature of powered mobility, as parents may see these devices as a negative symbol of disability. Therefore, parents need to be supported and educated on the potential benefits; likewise, guidance is needed to support wheelchair services to make balanced judgements about potential risks and harms. Very young children clearly need to be supervised in any early powered mobility, but this is the same for all young children, and thus should be approached in a developmentally appropriate manner. There was limited overall evidence about accidents and pain as powered mobility intervention outcomes; the nature of accidents and pain were well described, but the prevalence data came from a limited pool of studies.

In terms of key factors influencing feasibility and acceptability of initial uptake, as well as sustainable, long-term implementation, the 'fit' between the child, the equipment and the child's everyday environment (physical and social) was identified as critical. A good fit could make the powered mobility use sustainable and positive, and spiral into many new participation and development opportunities for the child. A poor fit could result in the child not using the equipment, accidents to the child and people around them, the child feeling negative, and the child missing out on participation and opportunities. Evidence underpinning 'fit' as an implementation concept came mainly from the textual data. Fit between the child, the equipment and their social and physical environment is likely to be critical for feasibility, acceptability and optimum effectiveness, and is thus a priority concept for further primary research.

Overall, this research found little evidence to suggest that 5 years of age is a meaningful or evidence-based cut-off point for powered mobility provision. Although few studies explored this explicitly, the implied view from the evidence appeared to be that powered mobility provision use was shaped by a child's developmental and cognitive profiles, not by their age. However, these considerations were often not made explicit, or were not consistent across the studies, and it was not possible to identify a uniform protocol of what powered mobility intervention elements to provide to which children, when and how. It would be a clinically valuable piece of work to seek to develop a national consensus protocol, and jointly identify the remaining key uncertainties and areas of equipoise.

The final logic model (see *Figure 8*) provides an overview of powered mobility outcomes and information about the direction of the outcomes and the overall evidence base. It is worth explicitly restating that we were unable to find conclusive evidence of the effectiveness or cost-effectiveness of powered mobility interventions, and that the description of the evidence base refers to the different types of evidence from across studies. The logic model should be read as a proposal for hypotheses from this review, as opposed to a statement of evidence of effects. In the model, solid arrows mean hypotheses that were developed based on consistent evidence across different study types. Dotted arrows mean tentative hypotheses implied in selected studies, but with limited evidence base across study types. Three of the concepts are not explicitly linked to the interventions, as we were not able to identify clear evidence about hypothesised causal chains linking them to the intervention. Arrows above the lines mean that the hypothesised relationship is positive (arrows up), negative (arrows down), mixed (one arrow down and one up) or uncertain (a question mark). Finally, as there is currently no established method for formally grading the certainty of mixed-methods synthesis findings, we were not able to provide such a formal grade for the overall synthesised concepts. Instead, the stated level of support (from strong to very low) refers to the overall range and depth of evidence across different types of studies that we were able to find for that concept. This is inevitably subjective and should be treated with caution. See also *Chapter 8*, *Strengths and weaknesses*, where the methodological limitations of the approach used to determine the stated level of support are further discussed.

Chapter 8 Discussion

The aim of this research was to assess whether or not earlier provision of powered mobility to very young children is more cost-effective than provision to children aged ≥ 5 years. This was not achievable because of the lack of published conclusive effectiveness evidence and non-existent cost-effectiveness evidence. For this reason, we re-evaluated the data we had, and subsequently felt that a different approach to evaluating effectiveness and performing economic analysis might be achievable. We therefore conducted two syntheses of the evidence, making use of the wide variety of evidence types, and conducted a budget impact analysis to identify the additional costs associated with increasing powered mobility provision for very young children.

Main findings

The main findings from this review are as follows. There are no formal, randomised, sufficiently powered evaluations of effectiveness of powered mobility on any outcomes in children aged either < 5 or ≥ 5 years. There were no economic data to allow us to determine the cost-effectiveness of powered mobility interventions for children; therefore, we are unable to make any definitive statements about the potential economic impacts of early powered mobility. It was also not possible to answer the question about the long-term implications of self-directed or independent mobility for very young children (as previously defined) compared with older children (≥ 5 years), again because of a lack of evidence.

However, the review identified an abundance of evidence, across age and diagnostic groups, that showed that powered mobility provision for children is feasible and acceptable. We further assessed the overall body of evidence to suggest, with strong certainty, that powered mobility may have a positive impact on children's movement and mobility across the age groups. In this, movement and mobility consisted of two dimensions: (1) 'movement for movement's sake', such as play-related movement; and (2) destination-focused mobility whereby a child moved to get from A to B. Although the direction of this effect was consistent, it was not possible to assess the size of a potential effect because of heterogeneity of the studies that contributed to this finding.

From descriptive and qualitative evidence, four further potential powered mobility outcomes were identified: (1) participation, play and social interaction; (2) autonomy, independence, choice and control, and freedom; (3) self-care; and (4) psychological outcomes. Evidence of effectiveness on all of these was scarce, with assessment of certainty ranging from low to moderate. The main focus of intervention descriptions to date has been on the powered mobility equipment and training; little was found about intervention elements targeting the wider context.

The main reported powered mobility safety events related to accidents and pain for the child, and parent and child feelings about the intervention and its consequences. The evidence about the frequency of these events was limited. Overall, the evidence suggested that a relevant lens for considering the safety of powered mobility may be that of a universal need for parents to balance the degree of risk and independence as they seek to support their child's development and growth.

The factors and processes that underpin acceptability, uptake and use of powered mobility included the 'fit' between a child's characteristics, the powered mobility equipment and the context (physical and social). The integration of self, device and environment appears to influence a child's potential to benefit from powered mobility, but is not necessarily related to a child's age. This is an important consideration in the conceptualisation of these interventions and in encouraging children to use powered mobility devices. When powered mobility interventions are presented as a means for play and moving for movement's sake, children may be more engaged and thus more likely to use the

device routinely. This could also be helpful for parents who are learning to adjust to their child's need for powered mobility and trying to support skill development at home.

For the specific comparison of powered mobility for very young children and children aged ≥ 5 years, the systematic review found, overall, little evidence to suggest a difference based on chronological age. There was some indication that developmental level, cognitive abilities or a child's size may influence the types of equipment that are suitable for a child and, for example, the training that a child may benefit from. The review found that formal powered mobility training is a potentially expensive intervention component, with equipoise over its format and delivery, its hypothesised importance to actual powered mobility uptake, and its effects.

Based on the results from the budget impact analysis, we predict that NHS spend on the provision of powered mobility to very young children is currently around £1.9M annually, which is < 2% of the overall reported CCG spend on NHS Wheelchair Services. We estimate that this figure could rise to up to £5.64M per annum with increased provision and integration of third-sector provision. We estimate that current NHS provision of early powered mobility covers only a limited proportion (50% at most) of very young children who could benefit from early powered mobility, with third-sector providers filling the gap in provision.

We developed a tariff of both NHS and non-NHS costs associated with powered mobility interventions for children. Owing to the lack of published evidence, it was necessary to derive the data from many different sources. The project advisory board and various NHS Wheelchair Services and providers were instrumental in identifying unit costs for the tariff. For assessing the costs and benefits, there is an overall lack of disaggregated data relating to very young powered mobility users, which makes it difficult to assess the costs and benefits for very young children, compared with older children. Further work is now needed to collect national data of paediatric wheelchair provision by age group and type of wheelchair.

Strengths and weaknesses

A key strength of this study was the synthesis of diverse types of evidence and perspectives. Including a wide variety of research types in our synthesis allowed a broad examination of the topic area, and allowed us to include the views and experiences of various key stakeholders. A focus on only quantitative evidence would have been of limited benefit, as there were few robust quantitative data to determine the effectiveness or cost-effectiveness of early powered mobility. The qualitative evidence was key to shaping our conceptualisations of the outcomes of powered mobility and determining the various factors that can influence feasibility and acceptability. The triangulation of different types of evidence allowed us to determine our confidence in the emerging concepts, and to highlight the gaps in evidence. Stakeholder involvement was also embedded in this project from the outset, which enabled us to optimise the relevance, usefulness and potential impact of the study by integrating expertise and insight from service users and providers at each stage. Stakeholder input will also enable us to develop dissemination materials that are engaging and relevant to a wide variety of audiences.

The primary limitation of this study relates to the lack of published evidence from formal, appropriately powered evaluations of effectiveness and cost-effectiveness, which meant that we were not able to answer our original research question. We utilised a wide range of established methods to attempt to configure the evidence in relation to the research question, pragmatically re-evaluating our approaches and adopting alternative methods to examine the data and persevere with our analyses. We feel that the resulting findings and syntheses offer various novel and useful insights into the potential effectiveness and economic costs of early powered mobility, and the priorities for future research.

The original intention was to develop an economic model to examine the long-term cost-effectiveness of early powered mobility. However, after the completion of the reviews, it became apparent that there were insufficient published data to develop a robust economic model. We had also intended to implement a value-of-information analysis as part of the model outputs. We intended to use this analysis to quantify the expected gain in net benefit from obtaining further information to inform any decisions. As highlighted throughout the report, there is uncertainty in both the provision pathway of early powered mobility provision and the quantification of the benefits that might be realised in very young children. Given these uncertainties, and the many areas where there was no, or very limited, evidence, we determined that it was not feasible to conduct the planned value-of-information analysis.

We accept that, with the budget impact analysis, many assumptions had to be made, but, whenever possible, the assumptions were based on evidence or expert advice, and we have been explicit about all sources of the data we used. One of the keys issues we experienced was in identifying the population of children who currently use powered mobility across the age range, and the number of children who could potentially benefit if early provision was standardised across the NHS. The published national data sets do not detail information by age for wheelchair provision; therefore, we had to extrapolate from population data to achieve our goal. This was a common issue, as the reporting of population and cost data in this area is quite limited. In several circumstances, we triangulated several sources of evidence to generate the costs. For this reason, we have presented wide ranges in costs as part of a simple sensitivity analysis to show the potential variance in our best estimates.

As wheelchair services and providers move towards use of electronic data management systems, it should become more feasible to collate data on types and cost of provision by age for use in future evaluations.

We also feel that it is important to comment further on the limitations in the approach used to make judgements about the level of support for the mixed-methods findings. As discussed in *Appendix 4*, there are no tools for assessing certainty or confidence in integrated quantitative and qualitative findings. A common approach is to undertake method-specific reviews and use method-specific tools such as Grading of Recommendations Assessment, Development and Evaluation (GRADE) and GRADE-CERQual, the assessments of which are brought together in an integrative framework such as the Developing and Evaluating Communication Strategies to Support Informed Decisions and Practice Based on Evidence (DECIDE) framework. In the current mixed-methods synthesis, there were few trials, but there were diverse sources of other types of evidence, which were considered useful. Using established approaches would not have allowed a full assessment of the evidence, so an integrative mixed-methods framework synthesis was used. In the absence of a validated tool to assess confidence in integrated findings, we developed an approach to assessing support for each concept. See for *Appendix 4* for details of the approach, and see *Table 11* for a worked example.

This approach was not developed using the extensive process used for the development of GRADE or GRADE-CERQual, and, as previously noted, the assessments must be interpreted with caution. Application of our approach also produced some methodological issues that are worthy of further discussion. The premise of the approach is that different types of evidence are considered uniquely useful for answering research questions. This includes acknowledgement that some types of data are more suited for answering some questions than others. For example, questions of effect are more usefully addressed by quantitative evidence, whereas questions about feasibility and acceptability benefit from qualitative evidence, although it is acknowledged that information about both issues can be found in other study types. One example of when the application of the approach produced a potential difference in interpretation relates to the assessment of feasibility and acceptability evidence in the interpretive evidence synthesis of the qualitative data. When GRADE-CERQual was applied, findings concerning these phenomena were assessed to be of high or moderate confidence. In contrast, in the mixed-methods synthesis, the absence of quantitative evidence regarding feasibility and acceptability was considered a limitation, and the evidence base was subsequently rated lower.

Overall, the approach presented in this report to assessing the level of support for mixed-method integrated quantitative and qualitative findings should be considered a useful first step to facilitate methodological debate on how best to do this. The approach used requires further development and refinement using an agreed consensus-based development method and further testing before it can be considered a validated approach.

Strengths and weaknesses in relation to other studies

Three seminal evidence syntheses have been conducted in this context: Bray *et al.*[160] synthesised evidence about the effectiveness, cost-effectiveness, barriers to/facilitators of provision, and current policy guidelines relating to paediatric wheelchair provision; Livingstone and Field[10,11] synthesised evidence about the impact of paediatric powered mobility use[10] and child/family user experiences.[11] No Cochrane reviews have been published in this area of research. Across the previous syntheses, it was consistently reported that powered mobility for children with mobility limitations may promote a range of beneficial outcomes, such as child-initiated movement, independent movement, social interaction, engagement in meaningful experiences and play, developmental attainment, reduced need for caregiver assistance and reduced parental stress. These effects have been found in younger children as well as in older children, and are, in turn, believed to affect the attainment of development milestones in early childhood and longer-term development.[22] However, the supporting evidence for these outcomes is often underpowered or of limited quality.

Although the existing syntheses offer a comprehensive picture of the literature at completion, they are limited in that they are now out of date. Furthermore, none of these syntheses attempted to explore the incremental benefits and costs of providing powered mobility for very young children, compared with later provision, and none summarised the evidence in the form of a causal, intervention-focused logic model that could be used to guide NHS planning and provision. In this respect, this study has numerous strengths over the previous syntheses, not least because the scope of this synthesis was broader and focused specifically on examining early powered mobility. However, one key issue is that we are still no closer to understanding the incremental benefits and costs of early powered mobility compared with later provision, because of the distinct lack of appropriate evidence. That being said, we now have a better understanding of the impact of age on a child's potential to benefit from powered mobility, and the likely arbitrariness of using the age of 5 years as a strict criterion for powered mobility provision.

This topic was prioritised by the users and providers of children's neurodisability services. Specifically, two of the 10 key questions prioritised in the recent James Lind Alliance Priority Setting Partnership for childhood neurodisability were as follows:[7]

> *Does appropriate provision of wheelchairs to enable independent mobility for very young children improve their self-efficacy? [Question 1.]*
>
> *Does the timing and intensity of therapies . . . alter the effectiveness of therapies for infants and young children with neurodisability, including those without specific diagnosis? What is the appropriate age of onset/strategies/dosage/direction of therapy interventions? [Question 4.]*

Although we have not been able to directly answer these questions because of the lack of conclusive evidence, we believe that the synthesised findings provide new insights into the topics posed by these questions, and we now have a clearer picture of how best to focus future research.

Meaning of the study

The evidence supported two key, distinct ways of conceptualising the primary powered mobility outcome, movement and mobility. The first was 'movement for movement's sake' (e.g. play, exploring, acting on the environment, autonomy, misbehaving, cognition and learning). This is relevant to all children, regardless of physical or cognitive ability, and appears to be the primary function of adapted ride-on cars and starter powered mobility devices. In this, two further outcome chains are implied: (1) developmental benefits achieved through movement and (2) preparing children for becoming powered wheelchair users. Of these, the former is relevant to all children, whereas the latter can be difficult to prospectively judge in terms of which children this applies to.

The second was destination-focused mobility (i.e. getting from A to B, a key mechanism of participating at home, in education, in the community). This is essentially the conceptualised purpose of adult powered wheelchairs, and, although our review did find evidence of the importance of this dimension for children, this was only one of the two dimensions, and not always the most important one, especially for the very youngest children. These two conceptualisations of powered mobility outcomes suggest that the provision of early powered mobility should not be considered through the same framework as provision of adult powered mobility, nor should it be treated as a stepping stone to powered wheelchair use. Instead, a key criterion for provision should include the potential of powered mobility to enable a child to move – for movement for movement's sake or for a child to go from A to B – to promote a child's development, play, exploration and independence.

We further conclude from this review that age-based provision is not the key factor in paediatric powered mobility provision. What appears to be coming from the evidence is that there are few data to support the restriction of powered mobility provision by age. Instead, the focus should be on providing powered mobility interventions in a developmentally appropriate manner, and focusing on 'movement for movement's sake' in the first instance and establishing good 'fit' between the child, their powered mobility device and the social/physical environment they inhabit. Therefore, comparing powered mobility effectiveness and cost-effectiveness before and after the age of 5 years may not be informative, as these interventions are likely to have different aims, purposes and conceptualisations. Furthermore, this is not simply a case of age appropriateness, as the focus should be on developmental appropriateness, regardless of age, because of the wide variation in the needs of children who use powered mobility.

In the context of NHS expenditure, it is apparent that significantly increasing the provision of powered mobility would, relatively speaking, not be a major economic expense. If we think of powered mobility interventions like orphan drugs (as they are relatively high cost and for a small population), we can see that powered mobility is a comparatively inexpensive way of improving long-term outcomes for children with disabilities. We believe that the number of children in England aged < 5 years who are likely to benefit from powered mobility in any year could be as high as 7000, for an intervention costing the NHS $<$ £5000 per child.

Unanswered questions and future research

The two key unanswered questions are whether or not early powered mobility is more cost-effective than powered mobility from the age of 5 years on, and what the optimal age is at which to provide powered mobility. In terms of unanswered questions and future research, four main conclusions could

be drawn. First, there is unlikely to be equipoise about the impact of powered mobility on movement and mobility in any age group, and benefits of a formal large-scale evaluation are likely to be limited. Second, powered mobility training is a potentially expensive component of this intervention, which could be provided more formally by the NHS and for which there seems to be a genuine equipoise. Although we were not able to identify one established training intervention protocol in the literature, there was evidence of emerging stability of key components and tailoring to specific populations (e.g. children with cognitive impairments), which could be built on with a view to a formal evaluation of cost-effectiveness of different training protocols. In this, no formal training may be a control group option, especially for children without cognitive impairments. Third, there is currently limited published large-scale evidence of the impact of powered mobility on all outcomes (including safety outcomes) other than movement and mobility. This is regardless of the children's age. Non-randomised designs could be considered for evaluating these impacts to enable parents, commissioners and providers to better understand the consequences of the intervention. The findings from the present review provide a framework for outcomes that such an evaluation may consider. Fourth, optimising powered mobility use and impact is likely to require a good fit between a child, their powered mobility equipment, and the wider context. To date, investigations of, and interventions for targeting, the context have so far been very limited, and further research to specifically investigate the fit could greatly enhance the impact of powered mobility interventions.

Broadly, priorities for future research should focus on:

- developing, implementing, evaluating and comparing different protocols, programmes and training packages for introducing and implementing early powered mobility at home, in education, in the community and so on
- evaluating different delivery models and care pathways for early powered mobility, including the most efficient way to commission/deliver early powered mobility in UK health systems, taking into account personalised wheelchair budgets and the different organisations and sectors involved in provision
- developing detailed and age-related national data sets on the provision/uptake of mobility equipment and related adaptations
- examining different conceptualisations of mobility and movement, in particular the concept of 'movement for movement's sake', and the potential benefits of structuring early powered mobility provision around this concept
- identifying and quantifying the developmental benefits brought about by early powered mobility and independent mobility in early childhood
- examining the long-term health, psychosocial, developmental and economic benefits of early powered mobility.

Collection and availability of such information will be essential for future work in this area, particularly with regard to establishing the effectiveness and cost-effectiveness of early powered mobility.

Conclusion and recommendations

Provision of independent mobility options, including powered mobility, should start as early as is feasible, and interventions should be tailored to each child's current and future developmental and cognitive abilities. The relationship between a child's abilities, impairments and potential to benefit from powered mobility may not be apparent until after powered mobility has been introduced. Therefore, the use of strict age- and skill-related eligibility criteria for powered mobility may exclude children who may otherwise have benefited from early powered mobility. Early powered mobility interventions should be developmentally appropriate and focus on 'movement for movement's sake'

in the first instance. Therefore, comparing powered mobility before and after the age of 5 years may be of little benefit, as these interventions are likely to have different aims, purposes and conceptualisations. Likewise, the use of the age of 5 years as a comparative cut-off point appears to be of limited benefit because of the wide variance in the needs and abilities of young children with mobility limitations. The physical and social environment around a child is also an important factor in achieving the best 'fit' between a child and powered mobility, and should be explicitly optimised as part of any powered mobility intervention.

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All authors contributed to the conduct of the overall project, interpretation of findings and to drafting, revising and approving the final report. All co-applicants were involved in conceiving and designing the project.

Data-sharing statement

This is an evidence synthesis project; therefore, no new data were generated. Further information can be obtained from the corresponding author.

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Appendix 1 List of project advisory group members

TABLE 39 List of project advisory group members

Name	Position	Expertise	Department	Organisation
Dr Tim Adlam	Clinical Scientist, Associate Professor of Global Disability Innovation, Principal Engineer with Designability	Design, implementation and evaluation of early powered mobility in low- and middle-income countries	Global Disability Innovation Hub	University College London, London, UK
Ms Amanda Allard	Assistant Director for Health	Health policy implementation; children and young people's involvement in decision-making	Not applicable	Council for Disabled Children, London, UK
Ms Rae Baines	Senior Children's Occupational Therapist	Implementation of early powered mobility	Not applicable	Designability, Bath, UK
Dr Johan Borg	Postdoctoral Fellow	Equitable provision and outcomes of assistive technology; socioeconomic impacts of disability	School of Medicine and Global Health	Lund University, Lund, Sweden
Ms Catharine Brown	Chief Executive of Designability	Technical and strategic development and implementation of early powered mobility	Not applicable	Designability, Bath, UK
Dr Sarah Crombie	Professional Lead Physiotherapist	Implementation of powered mobility with children and young people of all ages	Chailey Heritage Clinical Services	Sussex Community NHS Trust, Brighton, UK
Mr Lambert Felix	Systematic Reviewer, Physiotherapist	Physiotherapy management of long-term conditions; rehabilitation medicine	Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences	University of Oxford, Oxford, UK
Professor James C (Cole) Galloway	Director of the Paediatric Mobility Laboratory and Design Studio, Physical Therapist	Design, implementation, and evaluation of early powered mobility; founder of the GoBabyGo programme operating in 70 locations worldwide	Department of Physical Therapy	University of Delaware, Newark, DE, USA
Dr Jenny Gibson	Lecturer in Psychology and Education, Speech and Language Therapist	Allied health interventions and early years development in the context of childhood disability	Faculty of Education	University of Cambridge, Cambridge, UK

continued

TABLE 39 List of project advisory group members (*continued*)

Name	Position	Expertise	Department	Organisation
Dr Rosie Gowran	Lecturer in Occupational Therapy	Development of sustainable wheelchair and seating assistive technology provision	School of Allied Health	University of Limerick, Limerick, Republic of Ireland
Mr Simon Halsey	Director	Technical, strategic and commercial development and implementation of early powered mobility	Not applicable	TinyTrax, Bristol, UK
Professor Nigel Harris	Director of Innovation and Growth	Technical and strategic development and implementation of early powered mobility	West of England Academic Health Science Network	Academic Health Science Network, Bristol, UK
Ms Susan Hillman	Head of Rehabilitation Engineering and Aids for Living, Clinical Scientist, Trustee of the Posture and Mobility Group	Implementation of powered mobility across the lifespan	Department of Rehabilitation Engineering and Aids for Living	Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK
Ms Claire Holdcroft	Outreach Worker, Occupational Therapist	Implementation of powered mobility with children and young people affected by spinal muscular atrophy	Not applicable	Spinal Muscular Atrophy UK, Stratford-upon-Avon, UK
Ms Amanda Hopkin	Case Manager, Occupational Therapist	Implementation of powered mobility with children and young people of all ages	Not applicable	Social Return, Durham, UK
Ms Krys Jarvis	Service Manager, Chairperson of the NHS National Wheelchair Managers' Forum	Implementation of powered mobility across the lifespan	Shropshire Wheelchair and Posture Service	Shropshire Community Health NHS Trust, Shrewsbury, UK
Ms Maria Kemeys	Business Development Officer	Design and production of bespoke assistive technology for children and young people with mobility limitations	Cerebra Innovation Centre	Cerebra, Carmarthen, UK
Dr Lisa Kenyon	Associate Professor, Physical Therapist	Development, implementation, and evaluation of powered mobility	Department of Physical Therapy	Grand Valley State University, Allendale, MI, USA
Ms Roslyn Livingstone	Occupational Therapist, Clinical Instructor, Researcher	Development, implementation, and evaluation of early powered mobility	Faculty of Medicine	University of British Colombia, Vancouver, BC, Canada
Dr Sam Logan	Assistant Professor	Development, implementation, and evaluation of low-technology early powered mobility	College of Public Health and Human Sciences	Oregon State University, Corvallis, OR, USA
Dr Jane Mischenko	Lead Commissioner of Children and Maternity Services	NHS commissioning for children and young people with mobility limitations	Not applicable	NHS Leeds South and East Clinical Commissioning Group, Leeds, UK

TABLE 39 List of project advisory group members (*continued*)

Name	Position	Expertise	Department	Organisation
Dr Chris Morris	Senior Research Fellow in Child Health	Identification, prioritisation and measurement of health outcomes in childhood neurodisability	Peninsula Cerebra Research Unit	University of Exeter, Exeter, UK
Dr Lisbeth Nilsson	Occupational Therapist, Researcher	Implementation of powered mobility for people with cognitive impairments across the lifespan	Not applicable	Driving to Learn, Lund, Sweden
Ms Lisa Bazin and Mr Alex Ball	Parents, founders of A Very Special Journey campaign	Lived experience of early powered mobility. Their 3-year-old son has spinal muscular atrophy (type 2) and received powered mobility aged 21 months	Not applicable	Not applicable (UK)
Liz Golborne	Parent	Lived experience of early powered mobility. Her 18-year-old daughter has cerebral palsy and complex communication needs, and received powered mobility aged ≈ 4 years	Not applicable	Not applicable (UK)
Dr Karen Rispin	Associate Professor of Biology	Implementation and evaluation of powered mobility in low-income countries	Department of Biology and Kinesiology	LeTourneau University, Longview, TX, US
Ms Lauren Rosen	Physiotherapist, Strategic Leader within RESNA	Implementation of early powered mobility, development of national guidance on powered mobility for children and young people	Motion Analysis Centre	St Joseph's Children's Hospital and University of South Florida, Tampa, FL, USA
Ms Sarah Vines	Head of Mobility Services	Implementation of early powered mobility	QEF Mobility Services	QEF, Leatherhead, UK
Ms Sarah Wallace	Senior Mobility Therapist, Occupational Therapist	Implementation of early powered mobility	North West Assistive Technology Team	Whizz-Kidz, London, UK

QEF, Queen Elizabeth's Foundation for Disabled People; RESNA, Rehabilitation Engineering and Assistive Technology Society of North America.

Note

Members are listed in alphabetical order; affiliations were correct at the time of the study.

Appendix 2 Reporting summary for patient, public and stakeholder involvement

We used the Guidance for Reporting Involvement of Patients and the Public 2 (GRIPP2) (short-form) reporting checklist[161] to summarise reporting of patient, public and stakeholder involvement. Results are summarised as follows:

- Report the aim of PPI in the study – reported in *Chapter 3*, *Stakeholder involvement*.
- Provide a clear description of the methods used for PPI in the study – reported in *Chapter 3*, *Stakeholder involvement*.
- Outcomes – report the results of PPI in the study, including both positive and negative outcomes: the aspects of the study to which parents and young people contributed are reported in *Chapter 3*, *Stakeholder involvement*, and throughout *Chapter 4*, *Methods*. There are no negative effects to report. We are not yet able to report the results of the young people's involvement in dissemination, as these activities are currently under way.
- Outcomes – comment on the extent to which PPI influenced the study overall. Describe positive and negative effects – reported in *Chapter 8*, *Strengths and weaknesses*, and *Strengths and weaknesses in relation to other studies*, and throughout *Chapter 3*, *Stakeholder involvement*, and *Chapter 4*, *Methods*. There are no negative effects to describe.
- Comment critically on the study, reflecting on the things that went well and those that did not, so others can learn from this experience – we report the involvement of PPI positively throughout *Chapter 3*, *Stakeholder involvement*, *Chapter 4*, *Methods*, and *Chapter 8*, *Strengths and weaknesses*, and *Strengths and weaknesses in relation to other studies*; there are no negative effects to report. We anticipate being able to comment more critically on the involvement of the young person's group in disseminating findings; however, this work is currently in progress and will primarily be undertaken following the publication of this report. We intend to include commentary on this aspect of the study in a future publication.

Appendix 3 Illustrative example of keywords and search strategy for review 1

MEDLINE (via Ovid)

Date range searched: 1946 to June 2018.

Date searched: June 2018; updated in October 2019.

Search strategy

1. wheelchair.mp. or exp Wheelchairs/
2. ((power* or motoris* or assist*) adj5 (mobility* or locomotion or wheelchair* or pushchair* or buggy or equipment or scooter* or toy* or car)).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
3. ((independent* or 'self directed' or self* or autonomous or functional*) adj3 (mobil* or move* or limit* or mov* or walk* or crawl*)).ti,ab.
4. (child* or infant* or toddler or paediatric* or teen* or adolescen* or young adult* or youth* or juvenile* or young pe* or young men or young women).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5. 1 or 2 or 3
6. 4 and 5
7. limit 6 to ("newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)" or "young adult (19 to 24 years)"

Appendix 4 Rationale for the chosen approach to assessing the certainty in the body of evidence in the integrated mixed-methods evidence synthesis

Important general methodological considerations related to assessing certainty of a body of evidence in mixed-methods reviews

1. Mixed-methods reviews start with review questions that can be answered only through a combination of qualitative and quantitative information. A well-established principle of mixed-methods research is that mixed methods should be used only when the research question demands inclusion of both qualitative and quantitative data.[49,162] Therefore, from the outset, the assumption in mixed-methods reviews is that the relevant body of evidence needs to include both qualitative and quantitative information.
2. The principle of 'mixing' is key to the rigour and credibility of findings in mixed-methods reviews. That is, the straddling across the qualitative and quantitative, and bringing together methods and data from both (in contrast to conducting qualitative and quantitative research separately in a single study), underpins the methodological rigour and credibility of findings in mixed-methods studies, including mixed-methods reviews. To enable this, there is an abundance of published, converging literature on the principles to guide mixing.[49,163–165]
3. The synthesis is a key stage of mixing. Considering the importance of mixing (see point 2), the synthesis stage that brings together qualitative and quantitative data is key to the production of mixed-methods review findings. Arguably, the most robust, credible findings are the combined, mixed findings that provide the most complete body of evidence relevant to the research question (keeping in mind that a mixed-methods review starts on the premise that the review question can be answered only by such mixed evidence; see point 1). Therefore, there is an argument that it is the combined, mixed findings that should be graded.
4. The stated meaning of assessing (or 'grading') the certainty of a body of evidence is based on the review question and methodology. The concept of assessing, or grading, the certainty of a body of evidence originally comes from systematic reviews of RCTs, which seek to answer questions about effectiveness of interventions on predefined outcomes. In that context, the established meaning of grading refers to the assessment of confidence in how close the effect estimate is to that of the true effect.[52] The desire to apply the concept of grading to qualitative questions and syntheses has subsequently resulted in an adoption of a revised meaning for qualitative reviews. In them, grading refers to an assessment of the extent to which a review finding is a reasonable representation of the phenomenon of interest. Both GRADE and GRADE-CERQual were designed for a decision-making process whereby quantitative and qualitative reviews are conducted separately and then their findings and assessments of certainty (quantitative) and confidence (qualitative) are presented together in an evidence to decision framework.
5. There are published, converging principles for assessing the certainty of the findings from mixed-methods studies, but no agreed meaning of grading a body of evidence. The published principles related to assessing certainty of the findings from mixed-methods studies focus on the quality of the method and data obtained, and the credibility of the inferences and interpretations resulting from mixing the qualitative and quantitative data.[49] For the purposes of grading certainty in mixed-methods reviews, we summarise these as 'confidence that the identified concepts, variables and/or relationships are true', where 'true' is understood through dimensions of validity.

6. There is a lack of grading tools for bodies of evidence in mixed-methods reviews. A recent review found that, of the 17 systems for rating bodies of evidence identified, only one was developed with mixed-methods reviews in mind,[166] and that system[167] focused on improving and rating the quality of the reviews themselves, rather than grading the evidence. To overcome this issue, many decision-making contexts conduct method-specific quantitative and qualitative reviews separately, and then bring the findings together in an evidence to decision framework. However, it can be argued that this reduces the benefit of using a mixed-methods approach, in which the integration and mixing are viewed as the fundamental strengths (see points 1 and 2).
7. There is no consensus on whether or not to grade bodies of evidence in reviews that are mixed methods from the outset and that aim to combine quantitative and qualitative evidence using a common rubric. In summary, in the present mixed-methods review, we acknowledged the various methodological considerations and challenges to grading bodies of evidence in reviews that are mixed methods from the outset, as opposed to method-specific reviews that are subsequently brought together. On balance, we felt that it was important to provide some summary indication of the level of support that the evidence from the current mixed-methods review (that was mixed from the outset) provides for each of the concepts identified, while stopping short of claiming that we applied a validated approach to do so. The following section describes the pragmatic approach that we used to make judgements about the level of support for the mixed-method findings.

Approach to assessing certainty of the body of evidence in the present mixed-methods review

We ultimately adopted a pragmatic approach to grading. We specifically came up with an initial typology of levels of support that the evidence provided for concepts identified in the mixed-methods framework synthesis. As a result, we have provided an overall assessment about the level of support for each concept. Our approach to assessing level of support for each concept is detailed in *Box 2*. This assessment was informed by the application of the mixed-methods-specific criteria (see *Table 4*). To the mixed-methods-specific criteria we also added a criterion for publication bias. In addition, to maximise the transparency of the assessment, for each concept we noted any additional important methodological considerations related to the quality of the underpinning studies.

Having used this approach in the current review, we outline our experiences and observations in *Chapter 8*, *Strengths and weaknesses*, and make some recommendations about the need for further methodological research to develop a validated approach.

BOX 2 Assessment levels used to assess support for each concept in the mixed-methods synthesis

Strong support: converging evidence from a range of designs; no major gaps.

Moderate support: converging evidence from a range of designs; clear gaps in data or theory.

Low support: converging evidence from a limited pool of designs; clear gaps in data.

Very low support: converging evidence primarily from either qualitative or quantitative designs only; substantial gaps in data.

Inconsistent support: no converging evidence.

Appendix 5 List of included studies

Agrawal SK, Kang J, Chen X, Kim MJ, Lee Y, Kong SW, *et al.* Robot-enhanced mobility training of children with cerebral palsy: short-term and long-term pilot studies. *IEEE Syst J* 2016;**10**:1098–106.[63]

Bamer AM, Connell FA, Dudgeon BJ, Johnson KL. Frequency of purchase and associated costs of assistive technology for Washington State Medicaid program enrollees with spina bifida by age. *Disabil Health J* 2010;**3**:155–61.[55]

Berry ET, McLaurin SE, Sparling JW. Parent/caregiver perspectives on the use of power wheelchairs. *Pediatr Phys Ther* 1996;**8**:146–50.[133]

Bottos M, Bolcati C, Sciuto L, Ruggeri C, Feliciangeli A. Powered wheelchairs and independence in young children with tetraplegia. *Dev Med Child Neurol* 2001;**43**:769–77.[23]

Butler C. Effects of powered mobility on self-initiated behaviors of very young children with locomotor disability. *Dev Med Child Neurol* 1986;**28**:325–32.[89]

Butler C, Okamoto GA, McKay TM. Motorized wheelchair driving by disabled children. *Arch Phys Med Rehabil* 1984;**65**:95–7.[126]

Ceres R, Pons JL, Calderon L, Jimenez AR, Azevedo L. A robotic vehicle for disabled children. *IEEE Eng Med Biol Mag* 2005;**24**:55–63.[120]

Cerruti M, Biondi R. Timely insertion of electronic wheelchair in overall rehabilitation plan for cerebral palsy in young children: investigation on the opinion of parents. *Sci Riabil* 2010;**12**:14–23.[103]

Chen X, Ragonesi C, Galloway JC, Agrawal SK. Training toddlers seated on mobile robots to drive indoors amidst obstacles. *IEEE Trans Neural Syst Rehabil Eng* 2011;**19**:271–9.[64]

Cooper RA, Tolerico M, Kaminski BA, Spaeth D, Ding D, Cooper R. Quantifying wheelchair activity of children: a pilot study. *Am J Phys Med Rehabil* 2008;**87**:977–83.[168]

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Deitz J, Swinth Y, White O. Powered mobility and preschoolers with complex developmental delays. *Am J Occup Ther* 2002;**56**:86–96.[12]

Dennis CW, Stansfeld S, Larin HM. *Effect of Providing Powered Mobility on Infants' Social Behavior and Vocalization: Two Case Studies*. Paper presented at the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) annual conference, New Orleans, LA, 26–30 June 2017.[94]

Douglas J, Ryan M. A preschool severely disabled boy and his powered wheelchair: a case study. *Child Care Health Dev* 1987;**13**:303–9.[115]

Dunaway S, Montes J, O'Hagen J, Sproule DM, Vivo DC, Kaufmann P. Independent mobility after early introduction of a power wheelchair in spinal muscular atrophy. *J Child Neurol* 2013;**28**:576–82.[127]

Durkin J. Discovering powered mobility skills with children: 'Responsive partners' in learning. *Int J Ther Rehabil* 2009;**16**:331–41.[109]

Evans N, Baines R. Trends, goals and outcomes for children and families using early powered mobility in a charitable loan scheme. *J Enabling Technol* 2017;**11**:138–47.[62]

Evans S, Neophytou C, de Souza L, Frank AO. Young people's experiences using electric powered indoor–outdoor wheelchairs (EPIOCs): potential for enhancing users' development? *Disabil Rehabil* 2007;**29**:1281–94.[59]

Feldner H. Impacts of early powered mobility provision on disability identity: a case study. *Rehabil Psychol* 2019;**64**:130–45.[116]

Feldner HA, Logan SW, Galloway JC. Mobility in pictures: a participatory photovoice narrative study exploring powered mobility provision for children and families. *Disabil Rehabil Assist Technol* 2019;**14**:301–11.[60]

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Gehant BA. Evaluation of the CAPP cart. *Artif Limbs* 1971;**15**:16–24.[108]

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Guerette P, Furumasu J, Tefft D. The positive effects of early powered mobility on children's psychosocial and play skills. *Assist Technol* 2013;**25**:39–50.[124]

Hasdai A, Jessel AS, Weiss PL. Use of a computer simulator for training children with disabilities in the operation of a powered wheelchair. *Am J Occup Ther* 1998;**52**:215–20.[65]

Home AM, Ham R. Provision of powered mobility equipment to young children: the Whizz-Kidz experience. *Int J Ther Rehabil* 2003;**10**:511–7.[106]

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Huang HH, Galloway JC. Modified ride-on toy cars for early power mobility: a technical report. *Pediatr Phys Ther* 2012;**24**:149–54.[169]

Huang HH, Ragonesi CB, Stoner T, Peffley T, Galloway JC. Modified toy cars for mobility and socialization: case report of a child with cerebral palsy. *Pediatr Phys Ther* 2014;**26**:76–84.[17]

Huang HH, Chen YM, Huang HW. Ride-on car training for behavioral changes in mobility and socialization among young children with disabilities. *Pediatr Phys Ther* 2017;**29**:207–13.[78]

Huang HH, Chen YM, Huang HW, Shih MK, Hsieh YH, Chen CL. Modified ride-on cars and young children with disabilities: effects of combining mobility and social training. *Front Pediatr* 2017;**5**:299.[79]

Huang HH, Huang HW, Chen YM, Hsieh YH, Shih MK, Chen CL. Modified ride-on cars and mastery motivation in young children with disabilities: effects of environmental modifications. *Res Dev Disabil* 2018;**83**:37–46.[80]

Huhn K, Guarrera-Bowlby P, Deutsch JE. The clinical decision-making process of prescribing power mobility for a child with cerebral palsy. *Pediatr Phys Ther* 2007;**19**:254–60.[130]

Inman DP, Loge K, Cram A, Peterson M. Learning to drive a wheelchair in virtual reality. *J Spec Educ Technol* 2011;**26**:21–34.[54]

Jonasson M. The AKKA-board – performing mobility, disability and innovation. *Disabil Soc* 2014;**29**:477–90.[110]

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Jones MA, McEwen IR, Neas BR. Effects of power wheelchairs on the development and function of young children with severe motor impairments. *Pediatr Phys Ther* 2012;**24**:131–40.[14]

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Logan SW, Catena MA, Sabet A, Hospodar CM, Yohn H, Govindan A, Galloway JC. Standing tall: feasibility of a modified ride-on car that encourages standing. *Pediatr Phys Ther* 2019;**31**:E6–E13.[121]

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Appendix 6 Sample of excluded studies and reasons for exclusion

TABLE 40 Sample of excluded studies and reasons for exclusion

Study	Reason for exclusion
Andrich 2015[171]	Wrong population
Barnard 2010[172]	Wrong intervention. No outcomes
Bartonek 2012[173]	No empirical data. No outcomes
Bloeman 2015[174]	No powered mobility intervention. Wrong intervention
Bray 2014[160]	Wrong study design
Butler 2015[175]	Wrong publication type
Douglas 1988[176]	Duplicate of Douglas and Ryan.[115] No outcomes
Ekiz 2017[177]	Wrong intervention. No outcomes
Field 2016[178]	Wrong study design. No outcomes. Wrong intervention
Sanders 2018[179]	No empirical data. No outcomes

Appendix 7 Characteristics of included studies

TABLE 41 Characteristics of included studies

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Agrawal *et al.*[63]	2016	The Republic of Korea	Non-randomised controlled trial	N/A	Cerebral palsy	II–III	15 ($n = 5$ children in the short-term experiment; $n = 5$ children plus $n = 5$ controls in the long-term experiment)	Short-term experimental study: 18.6 ± 5.28 months; longer experimental study: 14.4 ± 2.33 months; control group in longer study were 28.8 ± 5.88 months	Not specified	Training sessions to drive two mobile robots, namely the PIONEER AT (Adept MobileRobots) and PowerBot (Adept MobileRobots), with identical conventional joysticks
Bamer *et al.*[55]	2010	USA	Non-comparative study	Secondary data analysis of electronic claims and eligibility records of persons covered by the Medicaid program over a 4-year period (2001–4) who had at least one service with a coded diagnosis of spina bifida	Spina bifida	N/A	0–15 years: $n = 323$; 16–25 years: $n = 215$	0–15, 16–25, and ≥ 26 years	Mixed; numbers not specified	Powered wheelchairs
Berry *et al.*[133]	1996	USA	Non-comparative study	Mixed methods – interviews and descriptive statistics	Cerebral palsy, myelomeningocele, Charcot–Marie–Tooth disease, VATER syndrome	N/A (study preceded GMFCS)	36	5–23 years	18 male, 18 female	Powered wheelchairs
Bottos *et al.*[23]	2001	Italy	Before-and-after study	N/A	Cerebral palsy	Assume IV/V	29	3–8 years	15 males, 14 females	Powered wheelchairs
Butler[89]	1986	USA	Interrupted time series	N/A	Myelomeningocele, spastic quadriplegic cerebral palsy, congenital malformation of limbs, arthrogryposis multiplex congenita and osteogenesis imperfecta	N/A (study preceded GMFCS)	6	23–38 months	Mixed; number of males and females not specified	Motorised wheelchair

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Butler *et al.*[126]	1984	USA	Non-comparative study	Data from daily records made by parents	Myelomeningocele, cerebral palsy, arthogryposis multiplex congenita, osteogenesis imperfecta, spinal muscular atrophy, four-extremity limb deficiency, quadriplegia of unknown aetiology	N/A (study preceded GMFCS)	13	20–37 months	6 females; 7 males	Motorised wheelchairs
Ceres *et al.*[120]	2005	Spain	Before-and-after study	N/A	Severe mobility limitations and reduced motor control	Not specified	5	3–7 years	Not specified	Assisted vehicle for disabled children: PALMA
Cerruti and Biondi[103]	2010	Italy	Non-comparative study	Online structured interview/survey	Cerebral palsy	Not specified	4	6–10 years	Not specified	Powered wheelchair
Chen *et al.*[64]	2011	USA	Before-and-after study	N/A	Spina bifida	Not specified	1	2 years	Male	Force-feedback on the joystick that trains the children to navigate while avoiding obstacles
Cooper *et al.*[168]	2008	USA	Non-concurrent cohort study	N/A	Muscular dystrophy, cerebral palsy, spina bifida, spinal cord injury	Not specified	9	8–16 years	5 males, 4 females	Powered wheelchair
Currier *et al.*[105]	2019	USA	Non-comparative study	Qualitative, grounded theory approach	Cerebral palsy; myotubular myopathy; tetraphocomelia	Not specified	8	2 years and 2 months to 3 years and 6 months	3 male, 5 female	Powered wheelchair
Deitz *et al.*[12]	2002	USA	Before-and-after study	N/A	Cerebral palsy (spastic quadriplegia), complex developmental delays	(Assume IV-V)	2	5 years	1 male, 1 female	Powered mobility riding toy (battery-operated ride-on car)

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Dennis *et al.*[94]	2017	USA	Before-and-after study	N/A	Severe undifferentiated hypotonia, and spastic diplegia cerebral palsy	4 for one child, not specified for the other	2	10 months and 22 months	Female	The WeeBot: a robotic mobility device assembled from commercially available components: a wheeled, aluminium frame is attached to a PIONEER 3DX (Adept MobileRobots) mobile robot. Attached to this frame is a Nintendo® Wii™ Balance Board (Nintendo Co., Ltd, Kyoto, Japan) with an infant seat mounted on top of it
Douglas and Ryan[115]	1987	England, UK	Non-comparative study	Clinical case study	Spinal cord injury (C4) at age 1 year	Not specified	1	4.5 years	Male	Powered wheelchair
Dunaway *et al.*[127]	2013	USA	Non-comparative study	Descriptive intervention study	Spinal muscular atrophy type I–II, congenital muscular dystrophy	Not specified	6	16–23 months at initial wheelchair evaluation, 24–34 months at wheelchair delivery	5 male, 1 female	Powered wheelchair
Durkin[109]	2009	England, UK	Non-comparative study	Qualitative, observation and focus groups, grounded theory approach	Cerebral palsy, hypoxic brain damage (CYP observations)	III-V (CYP observations)	CYP focus groups $n = 7$, professional focus groups $n = 22$, CYP observations $n = 11$	CYP focus groups: 9–12 years, CYP observations: 5–10 years	CYP focus groups: 3 male, 4 female; CYP observations: 5 female, 6 male	Powered wheelchair with three types of operational mode: freedrive, electronic track guidance system and systems collision avoidance device
Evans and Baines[62]	2017	England, UK	Non-comparative study	Mixed methods, descriptive statistics and thematic analysis	Cerebral palsy, spinal muscular atrophy, global developmental delay, arthrogryposis, spina bifida	Not specified	90	15–72 months	51 male, 39 female	Wizzybug
Evans *et al.*[59]	2007	England, UK	Non-comparative study	Qualitative, telephone questionnaire and interview	Muscular dystrophy, cerebral palsy, other	Not specified	13	10–18 years	13 male, 5 female	EPIOC
Feldner *et al.*[60]	2019	USA	Non-comparative study	Qualitative, ethnographic case study, photovoice	Cerebral palsy	Not specified	2	4 and 5 years	Male	Powered wheelchair and modified powered ride-on toy car
Feldner[116]	2019	USA	Non-comparative study	Qualitative, grounded theory approach	Quadriplegic cerebral palsy	Not specified	2	4 and 5 years	Male	Powered wheelchair; adapted mobility toy

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Flodin[122]	2007	Sweden	Non-comparative study	Longitudinal case study	Spinal muscular atrophy type II	Not specified	1	13 months at start of study	Female	Motorised walking aid
Frank *et al.*[131]	2012	England, UK	Non-comparative study	Qualitative – telephone interviews	Muscular dystrophy, cerebral palsy, spina bifida	Not specified	64	10–81 years	32 male, 32 female	Powered wheelchairs
Furumasu *et al.*[81]	1996	USA	Non-comparative study	Other; development of battery to assess wheelchair skills	Arthrogryposis, spinal muscular atrophy, spinal cord injury, other (e.g. amputee)	Not specified	24	18–36 months	Not specified	Powered mobility skills/ training programme
Furumasu[170]	2015	USA	Non-comparative study	Case studies	Cerebral palsy	Not specified	2	3.5 years (child 1); 7–17 years (child 2)	1 male, 1 female	Powered wheelchair
Galloway *et al.*[57]	2008	USA	Non-comparative	Descriptive intervention study	Down syndrome	Not specified	1	14 months	Male	Joystick-controlled mobile robot with cart
Gehant[108]	1971	USA	Non-comparative study	Quantitative, descriptive intervention study	Quadrimembral amputees	Not specified	11	6–14 years	4 male, 7 female	Motorised 'CAPP cart', powered by a 12-V battery, travels at a constant speed of 1.5 mph, controlled by a chin-controlled lever
Cronin[134]	2012	Republic of Ireland	Non-comparative study	Qualitative study, data obtained using semistructured interviews, interpretive phenomenological approach was used	Cerebral palsy-spastic diplegia; cerebral palsy – spastic quadriplegia, DiGeorge syndrome; osteogenesis imperfecta	Not specified	5 (parents of three young persons with mobility limitations)	13–18 years (children with mobility limitations whose parents were interviewed)	Not specified	Specialised wheelchair and specialised seating
Gudgeon and Kirk[99]	2015	England, UK	Non-comparative study	Qualitative: semistructured interviews, interpretative phenomenological analysis	Cerebral palsy, muscular dystrophy, spinal muscular atrophy, brain tumour	Not specified	9	7–16 years	7 male, 2 female	Powered wheelchair
Guerette *et al.*[124]	2013	USA	Before-and-after study	N/A	Cerebral palsy, arthrogryposis, congenital muscular dystrophy, osteogenesis imperfect, spinal muscular atrophy, spinal cord injury	Not specified	23	18 months–6 years	Not specified	Powered wheelchair

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Hasdai *et al.*[65]	1998	Israel	Controlled before-and-after study	N/A	Muscular dystrophy, cerebral palsy	Not specified	22	7–22 years	9 male, 13 female	Computer simulator driving programme
Home and Ham[106]	2003	England, UK	Non-comparative study	Retrospective survey with 24 open-ended questions	Cerebral palsy, spinal muscular atrophy	Not specified	331 families contacted; 61 questionnaires returned; 57 were included	< 7 years (most common age for issue of the powered wheelchair was 4 years)	33 (58%) male	Powered wheelchair
Huang and Chen[77]	2017	Taiwan	Non-randomised	N/A	Developmental delay, cerebral palsy, Down syndrome	Not specified	20	1–3 years	10 male, 10 female	Training to drive a modified, powered toy car
Huang *et al.*[78]	2017	Taiwan	Before-and-after study	N/A	Developmental delay, cerebral palsy, Down syndrome, other	Not specified	10	1–3 years; mean age 21.0 months (standard deviation 8.78 months)	6 female, 4 male	Ride-on car training for 9 weeks, (2 hours per session, two sessions per week)
Huang and Galloway[169]	2012	USA	Non-comparative study	Clinical case study	Cerebral palsy	IV	1	28 months	Female	Modified ride-on toy car
Huang *et al.*[80]	2018	Taiwan	Non-randomised controlled trial	N/A	Developmental delay; cerebral palsy; others	Not reported	15 (treatment group); 14 (control group)	1–3 years	7 males and 8 females in the treatment group; 5 males and 9 females in the control group	Modified ride-on cars and social interaction training programme
Huang *et al.*[17]	2014	Taiwan	Before-and-after study	N/A	Cerebral palsy	IV	1	21 months	Male	Modified powered toy car
Huang *et al.*[79]	2017	Taiwan	Non-randomised controlled trial	N/A	Developmental delay, cerebral palsy	Not specified	29 ($n = 15$ in the treatment group, $n = 14$ in the control group)	1–3 years	12 male, 17 female	2-hour ride-on car training sessions twice per week, for a total of 9 weeks, in the hospital environment
Huhn *et al.*[130]	2007	USA	Before-and-after study	N/A	Cerebral palsy	V	1	9 years	Female	Powered wheelchair; mid-wheel and rear-wheel drive
[a]Inman *et al.*[54]	2011	USA	Controlled before-and-after study	N/A	Orthopaedic impairments	Not specified	Not specified	3–15 years	Not specified	Mobility training platform and virtual training scenarios

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
[a]Inman *et al.*[54]	2011	USA	RCT	N/A	Cerebral palsy, Down syndrome	Not specified	13 (subjects who completed the trial)	4–20 years	7 female, 6 male	Virtual reality training motorised wheelchair training programme
Jonasson[110]	2014	Sweden	Non-comparative study	Qualitative, interviews	Severely disabled (specific medical conditions were not specified)	Not specified	Eight interviews, including three mothers of children with an AKKA-board in their homes	Not specified	Not specified	AKKA-board: a mobility device classified as an electric wheelchair that can be prescribed as an aid for severely disabled individuals offering mobility
Jones *et al.*[13]	2003	USA	Before-and-after study	N/A	Spinal muscular atrophy (type II)	Not specified	1	20 months at receipt of the intervention	Female	Powered wheelchair
Jones *et al.*[14]	2012	USA	RCT	N/A	Cerebral palsy, achondroplasia, Dandy–Walker syndrome, myotubular myopathy, congenital myopathy, hydrocephalus, myotonic dystrophy, failure to thrive, tetraphocomelia, progeria, arthrogryposis	IV–V	28	14–30 months	15 female, 13 male	Powered wheelchair
Kakimoto *et al.*[107]	2009	Japan	Non-comparative study	Description of prototype and evaluation of usefulness through tests by a boy and a girl with combined cerebral palsy	Cerebral palsy	IV–V	2	4 and 8 years	1 male, 1 female	Cart for mobility assistance: battery operated, joystick operated; a prototype cart for independent mobility assistance that allows users to get on while sitting in a chair with seating and positioning system
Kenyon *et al.*[75]	2017	USA	Before-and-after study	N/A	Cerebral palsy	V	1	3 years, 2 months	Female	Power mobility training (motorised platform)
Kenyon *et al.*[61]	2018	USA	Non-comparative study	Qualitative: focus groups and one-to-one interviews	Arthrogryposis multiplex congenita, acquired brain injury, cerebral palsy, Duchenne muscular dystrophy	Not specified	33 (parents and therapists)	6 months–7 years (children's age at starting to use powered mobility devices)	Not specified	Powered mobility device

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Kenyon *et al.*[86]	2017	USA	Before-and-after study	N/A	Cerebral palsy	III–V	3	17 months, 2 years, 5 months, and 3 years, 5 months	2 male, 1 female	Powered mobility device, powered mobility trainer platform
Kenyon[76]	2015	USA	Before-and-after study	N/A	Cerebral palsy	V	1	18 years	Female	Powered wheelchair training platform
Kornafel *et al.*[104]	2017	USA	Non-comparative study	Case report	Acute flaccid myelitis	Not specified	1	13 years	Male	Powered wheelchair
Larin *et al.*[129]	2012	USA	Non-comparative study	Description of children's capability to control the WeeBot	Cerebral palsy; Down syndrome	IV	3	15 months and 7 months	Male	Infants were seated over a PIONEER 3-DX mobile robot. Some used a Nintendo Wii Balance Board (the WeeBot) to control movement, others used a modified joystick
Logan *et al.*[88]	2014	USA	Before-and-after study	N/A	Down syndrome	Not specified	1	13 months	Female	Modified ride-on car, education, and training
Logan *et al.*[90]	2017	USA	Non-comparative study	Case description	Physical disability	Not specified	1	4.5 years	Male	Novel modified ride-on car for standing: modified 12-V, Fisher-Price Power Wheels Kawasaki (US$251.99) that travelled at two speeds forward, 2.5 and 5 mph, and one speed in reverse, 2.5 mph. A small activation switch
Logan *et al.*[118]	2016	USA	Before-and-after study (with caveat that the children did engage with the intervention at baseline)	N/A	Complex medical needs (diagnoses not specified)	Not specified	3	6 months, 19 months, 5 years 10 months	2 female, 1 male	Ride-on car
Logan *et al.*[87]	2018	USA	Before-and-after study	N/A	Cerebral palsy, 16p11.2 microdeletion, microcephaly	III	3	12–29 months	2 female, 1 male	Modified ride-on car, education, and training
Logan *et al.*[121]	2019	USA	Interrupted time series	N/A	Down syndrome	Not specified	4	The infants began the study at ages (months: days): 7:12, 7:19, 9:7; adjusted age 8:20 for prematurity, and 7:19	1 female, 3 male	Ride-on car that was modified to have a seated mode and a standing mode

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Lovett[113]	1988	England, UK	Before-and-after study	N/A	Profound and multiple learning disabilities ('Nonambulatory, profoundly mentally retarded'[113])	Not specified	4	3.1–13.4	1 female, 3 male	Microelectronic battery-operated car built on a standard go-kart frame onto which an infant safety seat has been attached, and discriminative cues
Lynch *et al.*[66]	2009	USA	Before-and-after study	N/A	Spina bifida	Not specified	1	7 months	Male	Powered mobility training
Marchal-Crespo *et al.*[67]	2010	USA	Controlled before-and-after study	N/A	Cerebral palsy	Not specified	1	8 years	Female	Robotic wheelchair trainer that steers itself along a course marked by a line on the floor using computer vision, haptically guiding the driver's hand in appropriate steering motions using a force feedback joystick
McCourt and Casey[68]	2016	Northern Ireland, UK	Non-comparative study	Descriptive intervention study	Cerebral palsy, Duchenne muscular dystrophy	Not specified	3	7–9 years	2 male, 1 female	EPIOC training/testing; exposure (time in years) to having an EPIC
McGarry *et al.*[69]	2012	Australia	Before-and-after study	Mixed-methods component	Cerebral palsy	V	4	4–14 years	2 male, 2 female	16 session Smart Wheelchair mobility training programme (an augmentative mobility aid equipped with specialised sensors and a computerised control system)
Mockler *et al.*[111]	2017	USA	Nested case–control study	Secondary analysis of data from intervention groups in two previous RCTs	Motor impairments that prevented independent mobility (diagnoses not specified)	Not specified	31	14–31 months at baseline	Not specified	Children practised manoeuvring individually customised powered wheelchairs for 12 months in natural environments
Montesano *et al.*[85]	2010	Spain	Non-comparative study	Case series (descriptive intervention study)	Cerebral palsy	Not specified	4	11–16 years	3 male, 1 female	Intelligent wheelchair (that allows the user to select arbitrary local destinations through a tactile screen interface, and incorporates an automatic navigation system that drives the vehicle, avoiding obstacles even in unknown and dynamic scenarios) and training

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Morère *et al.*[70]	2018	France	Non-RCT	N/A	Cerebral palsy	II–IV	12	8–24 years	8 male, 4 female	Wheelchair simulator: a virtual environment designed specifically for the purpose of this study and was modelled to accurately reflect the real outdoor environment of the rehabilitation centre. Simulations were conducted using ViEW (Virtual Electrical Wheelchair), a 3D wheelchair simulator designed in laboratory
Nicholson and Bonsall[84]	2002	England, UK	Non-comparative study	Survey of wheelchair services in England	Cerebral palsy, spinal muscular atrophy	Not specified	139 contacted, 97 replied	< 5 years	Not specified	Powered wheelchairs for indoor–outdoor use, and training
Nilsson *et al.*[73]	2010	Sweden	Nested case–control study	N/A	Profound cognitive disabilities and multivariate additional disabilities, or high risk of developing this condition (diagnoses not specified)	Not specified	45	12 months–52 years; five of the participants who were included in the training programme were aged between 1 and 6 years, two were between 7 and 20 years, and one was aged 35 years	20 female, 25 male	Powered wheelchair training
Nilsson *et al.*[117]	2011	Sweden	Non-comparative study	Qualitative, grounded theory approach with constant comparative analysis	Profound cognitive disabilities ($n = 45$); lesser degrees of cognitive disability ($n = 64$), including learning disability, neurodevelopmental disabilities, stroke, brain tumour, traumatic brain injury, or dementia	Not specified	45 (a further $n = 64$ with lesser degree of cognitive disability aged 16 months–86 years)	The age at inclusion was between 1 and 52 years, distributed as follows: 14 preschool children (1–6 years), 18 schoolchildren (7–20 years) and 13 adults (21–52 years)	Not specified	Joystick-operated powered wheelchair

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Nilsson and Nyberg[74]	2003	Sweden	Non-comparative study	Qualitative case studies using constant comparative analysis of video-recordings, field notes, and in-depth interviews	Profound cognitive disabilities (diagnoses not specified)	Not specified	2	4 and 5 years	1 male, 1 female	Intensive training in powered wheelchair
Odor and Watson[91]	1994	Scotland, UK	Non-comparative study	Case studies	Various (diagnoses not specified)	Not specified	13	The main group ($n = 10$) were aged from 3.5 to 15 years	2 female, 11 male	Smart wheelchair
Omori *et al.*[114]	2011	Japan	Non-comparative study	Case summaries	Athetoid cerebral palsy; physical disabilities	Not specified	2	1 first grader and 1 fourth grader	Female	Powered wheelchair with adapted support functions
Paulsson and Christoffersen[95]	1986	Sweden	Before-and-after study	N/A	Spina bifida, congenital injury of the spine, muscular atrophy, congenital amputations of the arms and legs, cerebral palsy	Not specified	12	2.5–5 years	Not specified	Electric go-karts
Pituch *et al.*[100]	2018	Canada	Non-comparative study	Semistructured qualitative interviews	Skeletal dysplasia, osteogenesis imperfecta, spinal muscular atrophy, arthrogryposis, cerebral palsy	Not specified	18: children ($n = 6$), parents ($n = 2$), rehabilitation centre occupational therapists ($n = 4$), and special needs school-based occupational therapists ($n = 6$)	Children were aged 12–18 years	4 male, 5 female (children)	Powered wheelchairs
Pope *et al.*[125]	1994	England, UK	Uncontrolled before-and-after study	N/A	Major postural deficit	Not specified	9	Not specified	Not specified	SAM system
Pritchard-Wiart *et al.*[58]	2019	Canada	Non-comparative study	Mixed-methods case series	Cerebral palsy ($n = 4$) and arthrogryposis and hypotonia ($n = 1$)	III, IV and V	5	13–58 months	4 male, 1 female	Modified toy car
Ragonesi *et al.*[96]	2010	USA	Controlled before-and-after study (socialisation outcome only; non-comparative study for mobility outcome)	N/A	Cerebral palsy	III	1	3 years	Male	Robot-enhanced mobility device – UD2 (University of Delaware)

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Ragonesi *et al.*[83]	2011	USA	Controlled before-and-after study (socialisation outcome only); before-after study for mobility outcome	N/A	Cerebral palsy	III	1	3 years	Male	Short-term, adult-directed power mobility and socialisation training; UD2 device also provided
Ragonesi and Galloway[72]	2012	USA	Non-comparative study	Descriptive intervention study	Cerebral palsy	Not specified	1	11 months	Female	Short-term intensive power mobility training
Ross *et al.*[97]	2018	USA	Before-and-after study	N/A – multiple single subjects repeated measures	Spastic triplegia cerebral palsy; hypotonic cerebral palsy; Dandy–Walker syndrome; Down syndrome; hemiplegic cerebral palsy; diplegic cerebral palsy	Not specified	5	15.8–20.2 months	1 female, 4 males	Ride-on car
Schoepflin *et al.*[128]	2011	USA	Non-comparative study	Descriptive intervention study	Cerebral palsy	I–V	1	49 months	Male	Bio-driven mobile assistive device that is controlled and driven by moving feet
Sharma and Morrison[98]	2007	England, UK	Non-comparative study	Case studies and survey	Various (diagnoses not specified)	Not specified	35 completed questionnaires were returned	22 months to 14 years	Not specified	Powered wheelchair
Smania *et al.*[123]	2012	Italy	Before-and-after study	N/A	Cerebral palsy	Not specified	1	11 years	1 male	Robotic walking aid
Sonday and Gretschel[101]	2016	South Africa	Non-comparative study	Qualitative case study	Cerebral palsy, spinal muscular atrophy	Not specified	2	8 and 9 years (both received the intervention at 2 years)	1 male, 1 female	Powered wheelchair

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Stokes *et al.*[92]	2014	USA	Before-and-after study	N/A	Pierre Robin sequence	Not specified	1	22 months	Male	Adapted ride-on toy
Tefft *et al.*[15]	2011	USA	Before-and-after study	N/A	Cerebral palsy, orthopaedic disabilities (arthrogryposis, spinal muscular atrophy, spinal cord injury, or osteogenesis imperfecta)	Not specified	Parents of 23 children with disabilities	Average age of children with cerebral palsy was 47.0 months (SD 11.1 months); average age of children with orthopaedic disabilities was 30.1 months (SD 6.0 months)	Not specified	Powered wheelchair
Torkia *et al.*[71]	2017	Canada	Non-comparative study	Qualitative research design with structured interviews was used	Muscular dystrophy ($n = 6$), cerebral palsy ($n = 4$), and a dual diagnosis of spinal cord injury and stroke ($n = 1$)	Not specified	15 clinicians and 11 children	Children were aged between 10 and 18 years	Not specified	miWe-CC simulator
Uyama and Hanaki[112]	2016	Japan	Non-comparative study	Cross-sectional questionnaire survey	Cerebral palsy, spondyloschisis, neuromuscular disease, arthropy	Not specified	318 facilities	Not specified	Not specified	Powered wheelchair
[a]Weinstein *et al.*[93]	2018	USA	Non-comparative study	Case summary	Rachischisis, complete spina bifida without acrania, and Chiari malformation type II with severe hydrocephalus	V	1	2 years and 10 months	Male	Powered wheelchair
[a]Weinstein *et al.*[93]	2018	USA	Non-comparative study	Case report	Rachischisis (cervical-level spina bifida)	V	1	2 years and 10 months	Male	Powered wheelchair

continued

TABLE 41 Characteristics of included studies (*continued*)

Study	Year of publication	Country	Study design classification	Description of non-comparative aspects	Health condition(s)	GMFCS level	Sample size (*n*)	Age	Gender	Intervention
Wiart *et al.*[132]	2003	Canada	Non-comparative study	Questionnaire survey	Cerebral palsy, bilateral, above-knee amputations, arthrogryposis, juvenile rheumatoid arthritis, osteogenesis imperfecta, spina bifida, tetraplegia due to spinal cord injury, traumatic brain injury, and non-progressive syndromes	Not specified	66 families	Mean age when wheelchair received: 7 years (SD 4.3 years)	40 male, 26 female	Powered wheelchair
Wiart *et al.*[102]	2004	Canada	Non-comparative study	Qualitative (phenomenological approach, interviews)	Cerebral palsy; myelomeningocele	Not specified	5	10–18 years	3 male, 2 female	Powered wheelchair
Zazula and Foulds[119]	1983	USA	Non-comparative study	Case summary	Multiple limb deficiencies	Not specified	1	11 months	Male	Electric cart
Zeng *et al.*[82]	2009	Singapore	Non-comparative study	Case report	Traumatic brain injury	Not specified	1 (5 in total, but only 1 was < 18 years)	16–48 years (note that only one participant was aged < 18 years)	4 male, 1 female	Collaborative Wheelchair Assistant (CWA; National University of Singapore), a robotic wheelchair that lets the user control the speed and provides guiding assistance along virtual paths programmed in software; also training

3D, three-dimensional; CAPP, Child Amputee Prosthetics Project; CYP, children and young people; EPIC, electric powered indoor wheelchair; miWe-CC, McGill immersive Wheelchair – Community Centre; mph, miles per hour; N/A, not applicable; PALMA, Plataforma de Apoyo Lúdico a la Movilidad Alternativa (assistive platform for alternative mobility); SAM, seating and mobility; SD, standard deviation; VATER, vertebrae, anus, trachea, esophagus and renal.

a Reference reports two studies.

Appendix 8 Quality appraisal results

TABLE 42 Quality appraisal results for RCTs that were assessed using the Cochrane risk-of-bias tool ($n = 2$)

Study	Randomisation process	Deviations from the intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Jones *et al.*[14]	Low	No agreement between reviewers	Some concerns	Some concerns	No agreement between reviewers	Some concerns
Inman *et al.*[54]	High	Some concerns	Low	Low	Some concerns	High

TABLE 43 Quality appraisal results for studies that were assessed using the RTI's bank of questions ($n = 66$)

Study	Outcome assessor blinded?	Valid and reliable measures for inclusion/exclusion criteria?	Valid and reliable measures for exposure/intervention?	Valid and reliable measures for participant health benefits and harms?	Attrition/retention reported?	Inclusion/exclusion criteria and recruitment strategy clearly reported?	Valid and reliable measures to assess confounding?	Any attempt to balance the allocation between the groups or match groups?
Ceres *et al.*[120]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	No	Partially yes	No	N/A
Chen *et al.*[64]	No or cannot determine	N/A	Yes	Partially yes	N/A	Partially yes	No	N/A
Cooper *et al.*[168]	No	Partially yes	Yes	Partially yes	Partially yes	Partially yes	Yes	N/A
Deitz *et al.*[12]	Yes	N/A	Partially yes	Partially yes	Yes	Partially yes	Partially yes	N/A
Furumasu[170]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	N/A	No	No	N/A
Douglas and Ryan[115]	No or cannot determine	N/A	No	No	N/A	N/A	No	N/A
Dunaway *et al.*[127]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	Yes	Partially yes	Partially yes	N/A
Flodin[122]	N/A	N/A	No or cannot determine	No or cannot determine	N/A	N/A	No or cannot determine	N/A
Furumasu *et al.*[81]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	No	No	No or cannot determine	N/A
Galloway *et al.*[57]	No	No or cannot determine	Yes	Yes	N/A	Partially yes	No or cannot determine	N/A
Gehant[108]	No or cannot determine	Partially yes	No or cannot determine	No or cannot determine	Yes	Partially yes	Partially yes	N/A
Guerette *et al.*[124]	No	Partially yes	Partially yes	Partially yes	Yes	Partially yes	Partially yes	N/A
Hasdai *et al.*[65]	Partially yes	Partially yes	Partially yes	Partially yes	No or cannot determine	Partially yes	Partially yes	Partially yes
Home and Ham[106]	No	Partially yes	No or cannot determine	No or cannot determine	Yes	Partially yes	No	N/A
Huang *et al.*[17]	No	N/A	Partially yes	Partially yes	N/A	Partially yes	No	N/A

Study	Outcome assessor blinded?	Valid and reliable measures for inclusion/ exclusion criteria?	Valid and reliable measures for exposure/ intervention?	Valid and reliable measures for participant health benefits and harms?	Attrition/ retention reported?	Inclusion/exclusion criteria and recruitment strategy clearly reported?	Valid and reliable measures to assess confounding?	Any attempt to balance the allocation between the groups or match groups?
Huang and Galloway[169]	N/A	N/A	N/A	No or cannot determine	N/A	No	No or cannot determine	N/A
Huang and Chen[77]	Yes	Yes	No or cannot determine	Partially yes	Partially yes	Partially yes	No or cannot determine	No
Huang *et al.*[78]	No or cannot determine	Partially yes	No or cannot determine	Yes	Partially yes	Partially yes	Partially yes	No
Huang *et al.*[79,80] (same study)	No or cannot determine	Partially yes	Yes	Partially yes	N/A	Partially yes	No or cannot determine	N/A
Huhn *et al.*[130]	N/A	N/A	No or cannot determine	Partially yes	N/A	N/A	No or cannot determine	N/A
Inman *et al.*[54]	N/A	Yes	Partially yes	N/A	No	Partially yes	N/A	N/A
Jones *et al.*[13]	N/A	N/A	No or cannot determine	Yes	N/A	N/A	No	N/A
Kakimoto *et al.*[107]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	N/A	Partially yes	No or cannot determine	N/A
Kenyon *et al.*[76]	N/A	N/A	No or cannot determine	Yes	N/A	N/A	No	N/A
Kenyon *et al.*[86]	No or cannot determine	Partially yes	No or cannot determine	Yes	No or cannot determine	Partially yes	No or cannot determine	N/A
Kenyon *et al.*[75]	No or cannot determine	Partially yes	No or cannot determine	Yes	Yes	Partially yes	No or cannot determine	N/A
Kornafel *et al.*[104]	N/A	N/A	No	Partially yes	N/A	N/A	Partially yes	N/A
Larin *et al.*[129]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	N/A	No or cannot determine	No or cannot determine	N/A

continued

TABLE 43 Quality appraisal results for studies that were assessed using the RTI's bank of questions ($n = 66$) (*continued*)

Study	Outcome assessor blinded?	Valid and reliable measures for inclusion/ exclusion criteria?	Valid and reliable measures for exposure/ intervention?	Valid and reliable measures for participant health benefits and harms?	Attrition/ retention reported?	Inclusion/exclusion criteria and recruitment strategy clearly reported?	Valid and reliable measures to assess confounding?	Any attempt to balance the allocation between the groups or match groups?
Logan *et al.*[88]	No or cannot determine	Partially yes	Partially yes	Partially yes	N/A	Partially yes	No	N/A
Logan *et al.*[87]	Partially yes	No or cannot determine	Partially yes	Partially yes	No or cannot determine	No or cannot determine	No	N/A
Logan *et al.*[118]	No or cannot determine	No or cannot determine	Yes	Partially yes	Yes	No or cannot determine	No	N/A
Logan *et al.*[121]	No or cannot determine	Partially yes	Partially yes	Partially yes	Partially yes	No or cannot determine	No	N/A
Agrawal *et al.*[63]	Yes	Yes	No or cannot determine	Yes	Yes	Yes	No or cannot determine	Partially yes
Bamer *et al.*[55]	N/A	Yes	N/A	N/A	N/A	Partially yes	No or cannot determine	N/A
Dennis *et al.*[94]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A
Butler[89]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A
Bottos *et al.*[23]	No or cannot determine	No or cannot determine	No or cannot determine	Yes	Yes	No or cannot determine	No or cannot determine	N/A
Butler *et al.*[126]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A
Paulsson and Christoffersen[95]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	Yes	No or cannot determine	No or cannot determine	N/A
Logan *et al.*[90]	No or cannot determine	N/A	No or cannot determine	Partially yes	Yes	Partially yes	No or cannot determine	N/A
Lovett[113]	No or cannot determine	No or cannot determine	Partially yes	No	Yes	No or cannot determine	No or cannot determine	N/A

Study	Outcome assessor blinded?	Valid and reliable measures for inclusion/ exclusion criteria?	Valid and reliable measures for exposure/ intervention?	Valid and reliable measures for participant health benefits and harms?	Attrition/ retention reported?	Inclusion/exclusion criteria and recruitment strategy clearly reported?	Valid and reliable measures to assess confounding?	Any attempt to balance the allocation between the groups or match groups?
Lynch *et al.*[66]	No	N/A	Yes	Yes	N/A	N/A	No or cannot determine	N/A
Marchal-Crespo *et al.*[67]	No or cannot determine	No or cannot determine	No or cannot determine	No or cannot determine	Yes	No or cannot determine	No or cannot determine	No
McCourt and Casey[68]	Yes	No or cannot determine	No or cannot determine	Partially yes	N/A	Yes	No or cannot determine	N/A
Mockler *et al.*[111]	N/A	N/A	Partially yes	Yes	N/A	Yes	Yes	N/A
Montesano *et al.*[85]	No or cannot determine	No or cannot determine	Partially yes	Partially yes	Yes	Yes	No or cannot determine	N/A
Morère *et al.*[70]	No or cannot determine	Yes	Partially yes	No	Yes	Partially yes	No or cannot determine	No
Nicholson and Bonsall[84]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nilsson and Nyberg[74]	No or cannot determine	No or cannot determine	No or cannot determine	No	Yes	Partially yes	No or cannot determine	N/A
Odor and Watson[91]	No or cannot determine	No or cannot determine	No or cannot determine	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A
Omori *et al.*[114]	No	N/A	No	No	N/A	No or cannot determine	No or cannot determine	N/A
Pope *et al.*[125]	N/A	Yes	Partially yes	Partially yes	Yes	Partially yes	No or cannot determine	N/A
Ragonesi *et al.*[96]	No	N/A	Partially yes	Partially yes	N/A	N/A	N/A	N/A
Ragonesi *et al.*[83]	No	N/A	Partially yes	Partially yes	N/A	N/A	No or cannot determine	N/A
Ragonesi and Galloway[72]	No	N/A	Partially yes	No or cannot determine	N/A	N/A	No or cannot determine	N/A
Ross *et al.*[97]	No	Yes	Yes	Yes	Yes	Partially yes	Partially yes	No

continued

TABLE 43 Quality appraisal results for studies that were assessed using the RTI's bank of questions ($n = 66$) (*continued*)

Study	Outcome assessor blinded?	Valid and reliable measures for inclusion/ exclusion criteria?	Valid and reliable measures for exposure/ intervention?	Valid and reliable measures for participant health benefits and harms?	Attrition/ retention reported?	Inclusion/exclusion criteria and recruitment strategy clearly reported?	Valid and reliable measures to assess confounding?	Any attempt to balance the allocation between the groups or match groups?
Schoepflin *et al.*[128]	No or cannot determine	No or cannot determine	No or cannot determine	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A
Sharma and Morrison[98]	No or cannot determine	No or cannot determine	N/A	N/A	No	Partially yes	N/A	N/A
Smania *et al.*[123]	No	N/A	No or cannot determine	Yes	N/A	Partially yes	N/A	N/A
Stokes *et al.*[92]	No	N/A	No or cannot determine	Yes	N/A	N/A	N/A	N/A
Tefft *et al.*[15]	No or cannot determine	Partially yes	Yes	Yes	Yes	Partially yes	No or cannot determine	N/A
Uyama and Hanaki[112]	N/A	No or cannot determine	Partially yes	Partially yes	Yes	Partially yes	N/A	N/A
Weinstein *et al.*[93]	N/A	N/A	No or cannot determine	No or cannot determine	N/A	N/A	N/A	N/A
Wiart *et al.*[132]	N/A	Partially yes	Yes	No	Yes	Partially yes	N/A	N/A
Zazula and Foulds[119]	No	N/A	Partially yes	No	N/A	N/A	N/A	N/A
Zeng *et al.*[82]	No or cannot determine	No or cannot determine	No or cannot determine	Partially yes	Yes	No or cannot determine	No or cannot determine	N/A

N/A, not applicable.

TABLE 44 Quality appraisal assessments for qualitative studies that were assessed using the CASP qualitative checklist ($n = 18$)

Study	Clear statement of aims?	Qualitative methodology appropriate?	Research design appropriate?	Recruitment strategy appropriate?	Data collected in a way that addressed the issue?	Researcher–participant relationship considered?	Ethics issues considered?	Data analysis rigorous?	Clear statement of findings?
Currier *et al.*[105]	Yes	Yes	Unclear	Unclear	Yes	No	Unclear	Yes	No
Evans *et al.*[59]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pituch *et al.*[100]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes
Nilsson *et al.*[117]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Nilsson and Nyberg[74]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	No	Yes	Yes
Kenyon *et al.*[61]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes
Jonasson[110]	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	No	Cannot tell	Cannot tell	Yes
Gudgeon and Kirk[99]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes
Wiart *et al.*[102]	Yes	Yes	Yes	Cannot tell	Yes	No	Yes	Yes	Yes
Frank *et al.*[131]	Yes	Yes	Cannot tell	Yes	No	Yes	Yes	Cannot tell	Yes
Feldner[116]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Yes	No	Cannot tell
Feldner *et al.*[60]	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Durkin[109]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes
Cronin[134]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes
Berry *et al.*[133]	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	No	Cannot tell	Yes
Torkia *et al.*[71]	Yes	Yes	Yes	Cannot tell	Yes	No	Yes	Cannot tell	Yes
Sonday and Gretschel[101]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell
Cerruti and Biondi[103] (in Italian; could not appraise)	–	–	–	–	–	–	–	–	–

TABLE 45 Quality appraisal assessments for mixed-methods studies that were assessed using the MMAT[a] ($n = 3$)

	Screening questions			Qualitative				Quantitative				Mixed methods		
Study	1	2	3	1.1	1.2	1.3	1.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3
Evans *et al.*[59]	Yes	Yes	Yes	Yes	Cannot tell	No	No	Yes	Yes	Yes	Yes	Yes	No	No
McGarry *et al.*[69]	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	N/A	Yes	Yes	Yes
Pritchard-Wiart *et al.*[58]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Unclear	Unclear	Yes	Yes	No	No

N/A, not applicable.
a See Pace *et al.*[46] for the full list of MMAT questions.

Appendix 9 Number of included studies by intervention element

TABLE 46 Number of included studies by intervention element

Intervention element	Number of studies	Intervention description	Studies
Powered mobility equipment for the child	62	Powered wheelchairs, motorised wheelchairs, assisted vehicle, ride-on toy, ride-on car, WeeBot, EPIOC, powered ride-on toy, motorised walking aid, mobile robot, motorised CAPP cart, specialised wheelchair, AKKA-board, cart for mobility assistance, powered mobility device, mobile robot, battery-operated car, Smart wheelchair, electrical go-karts, SAM system, robot-enhanced mobility device, robotic walking aid, ride-on toy, electric cart	Deitz *et al.*,[12] Jone *et al.*,[13] Jones *et al.*,[14] Tefft *et al.*,[15] Huang *et al.*,[17] Bottos *et al.*,[23] Bamer *et al.*,[55] Galloway *et al.*,[57] Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] Furumasu *et al.*,[81] Logan *et al.*,[87] Butler,[89] Cooper *et al.*,[168] Huang and Galloway,[169] Kornafel *et al.*,[104] Logan *et al.*,[90,118] Mockler *et al.*,[111] Odor and Watson,[91] Pope *et al.*,[125] Smania *et al.*,[123] Stokes *et al.*,[92] Uyama and Hanaki,[112] Zazula and Foulds,[119] Durkin,[109] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Home and Ham,[106] Huhn *et al.*,[130] Kakimoto *et al.*,[107] Lovett,[113] Omori *et al.*,[114] Schoepflin *et al.*,[128] Weinstein *et al.*,[93] Larin *et al.*,[129] Nilsson *et al.*,[117] Ragonesi *et al.*,[96] Ross *et al.*,[97] Sharma and Morrison,[98] Cerruti and Biondi,[103] Gehant,[108] Jonasson,[110] Douglas and Ryan,[115] Ceres *et al.*,[120] Flodin,[122] Guerette *et al.*,[124] Butler *et al.*,[126] Dunaway *et al.*,[127] Frank *et al.*,[131] Wiart *et al.*,[132] Berry *et al.*[133] and Cronin[134]
Adaptations to physical environment (e.g. ramps, lifts)	0	N/A	N/A
Adaptations to policies and practices (e.g. nurseries, leisure centres)	0	N/A	N/A
Training for the child and people around the child in the use of the equipment	20	Training sessions to drive mobile robots, force-feedback on the joystick that trains the children to navigate while avoiding obstacles, powered mobility skills/training programme, computer simulator driving programme, training to drive a modified, powered toy car, ride-on car training for 9 weeks (2 hours per session, two sessions per week), ride-on car training sessions, mobility training platform and virtual training scenarios, power wheelchair training platform, power mobility training, robotic wheelchair trainer, wheelchair simulator, powered wheelchair training, miWe-CC simulator	Inman *et al.*,[54] Agrawal *et al.*,[63] Chen *et al.*,[64] Hasdai *et al.*,[65] Lynch *et al.*,[66] Marchal-Crespo *et al.*,[67] McCourt and Casey,[68] McGarry *et al.*,[69] Morère *et al.*,[70] Torkia *et al.*,[71] Ragonesi and Galloway,[72] Nilsson *et al.*,[73] Nilsson and Nyberg,[74] Kenyon *et al.*,[75,76] Huang and Chen,[77] Huang *et al.*[78,79] and Furumasu *et al.*[81]

continued

TABLE 46 Number of included studies by intervention element (*continued*)

Intervention element	Number of studies	Intervention description	Studies
Maintenance and review including of the equipment	0	N/A	N/A
Equipment and training	7	As above	Zeng *et al.*,[82] Ragonesi *et al.*,[83] Nicholson and Bonsall,[84] Montesano *et al.*,[85] Kenyon *et al.*[86] and Logan *et al.*[87,88]

CAPP, Child Amputee Prosthetics Project; miWe-CC, McGill immersive Wheelchair – Community Centre; N/A, not applicable; SAM, seating and mobility.

Appendix 10 The GRADE-CERQual assessment of confidence in the qualitative thematic synthesis findings

TABLE 47 The GRADE-CERQual assessment of confidence in the qualitative thematic synthesis findings

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
1.1: Acceptance of powered mobility – parents	Feldner *et al.*,[60] Kenyon *et al.*,[61] McGarry *et al.*,[69] Pituch *et al.*,[100] Wiart *et al.*,[102] Feldner,[116] Cerruti and Biondi,[103] and Cronin[134]	Moderate methodological limitations • Two studies did not adequately consider researcher–participant relationship (a further three papers did not clearly report researcher–participant relationship) and one study did not conduct rigorous data analysis • Lack of clarity – one study did not clearly report consideration of ethics issues	Minor concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	No or very minor concerns about adequacy: eight studies, which, together, offer rich data	No or very minor concerns about relevance: four studies included data relating to very young children; and all studies were from high-income settings	High confidence	Eight studies with moderate methodological limitations. Minor concerns about coherence. No or very minor concerns about adequacy and relevance
1.2: Acceptance of powered mobility – children	Kenyon *et al.*[61] and Durkin[109]	Minor methodological limitations: neither study clearly reported researcher–participant relationship	Minor concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Serious concerns about adequacy: only two studies, which, together, offer thin data	Minor concerns about relevance: both studies included data relating to very young children; and both studies were from high-income settings. One study reported data relating to typically developing children	Low confidence	Two studies with minor methodological limitations. Minor concerns about coherence and relevance. Serious concerns about adequacy

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
2.1: Developing powered mobility skills and competency – early introduction	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] Evans and Baines,[62] Durkin[109] and Currier *et al.*[105]	Minor methodological limitations: • Three studies did not adequately consider researcher–participant relationship (the remaining two studies did not clearly report researcher–participant relationship) and one study did not clearly report study findings • Lack of clarity – one study did not clearly report data analysis methods, one study did not clearly report consideration of ethics issues and one study did not clearly report research design or recruitment methods	Minor concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Moderate concerns about adequacy: five studies, which, together, offer rich data	No or very minor concerns about relevance: four studies included data relating to very young children; and all studies were from high-income settings	Moderate confidence	Five studies with minor methodological limitations. Minor concerns about coherence. Moderate concerns about adequacy due to limited data. No or very minor concerns about relevance
2.2: Developing powered mobility skills and competency – time and support	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] Evans and Baines,[62] Nilsson and Nyberg,[74] Durkin,[109] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Currier *et al.*,[105] Feldner,[116] Jonasson[110] and Berry *et al.*[133]	Moderate methodological limitations: • Four studies did not adequately consider researcher–participant relationship (the eight remaining studies did not clearly report researcher–participant relationship), one study did not sufficiently consider ethics issues (four further studies lacked clarity in ethics considerations) and one study did not clearly report study findings (one further study lacked clarity in reporting findings)	No or very minor concerns about coherence	No or very minor concerns about adequacy: 12 studies, which, together, offer rich data	Minor concerns about relevance: six studies included data relating to very young children and one study was from an upper middle-income country. One study reported data relating to typically developing children	High confidence	Twelve studies with moderate methodological limitations. No or very minor concerns about coherence and adequacy. Minor concerns about relevance

continued

TABLE 47 The GRADE-CERQual assessment of confidence in the qualitative thematic synthesis findings (*continued*)

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
		• Lack of clarity – five studies did not clearly report recruitment methods, four studies did not clearly report data analysis methods, two studies did not clearly report data collection methods and two studies did not clearly report research design					
2.3: Developing powered mobility skills and competency – play and experiential learning	Pritchard-Wiart *et al.*,[58] Kenyon *et al.*,[61] Evans and Baines,[62] Durkin,[109] Pituch *et al.*,[100] Currier *et al.*[105] and Nilsson *et al.*[117]	Minor methodological limitations: • Three studies did not adequately consider researcher–participant relationship (a further three papers did not clearly report researcher–participant relationship) and two studies did not clearly report study findings • Lack of clarity – one study did not clearly report data analysis methods, one study did not clearly report research design or recruitment methods and one study lacked clarity in ethics considerations	Minor concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Minor concerns about adequacy: seven studies, which, together, offer moderately rich data	No or very minor concerns about relevance: five studies included data relating to very young children; and all studies were from high-income settings	High confidence	Seven studies with minor methodological limitations. Minor concerns about coherence and adequacy. No or very minor concerns about relevance

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
3.1: Using powered mobility safely – conceptualising safety	Evans *et al.*,[59] Kenyon *et al.*,[61] Durkin[109] and Gudgeon and Kirk[99]	Minor methodological limitations: • One study did not sufficiently consider ethics issues and one study did not adequately consider researcher–participant relationship (a further two papers did not clearly report researcher–participant relationship) • Lack of clarity – one study did not clearly report recruitment or data collection methods, and two studies lacked clarity in reporting findings	Moderate concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Moderate concerns about adequacy: four studies, which, together, offer moderately thin data	Minor concerns about relevance: one study included data relating to very young children; and all studies were from high-income settings	Moderate confidence	Four studies with minor methodological limitations. Moderate concerns about coherence and adequacy. Minor concerns about relevance
3.2: Using powered mobility safely – cognitive ability	Evans *et al.*,[59] Kenyon *et al.*[61] and Evans and Baines[62]	Minor methodological limitations: • One study did not adequately consider researcher–participant relationship (one other study did not clearly report researcher–participant relationship) • Lack of clarity – one study did not clearly report data analysis methods	Moderate concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Serious concerns about adequacy: three studies, which, together, offer thin data	No or very minor concerns about relevance: two studies included data relating to very young children; and all studies were from high-income settings	Low confidence	Three studies with minor methodological limitations. Moderate concerns about coherence. Serious concerns about adequacy due to limited, thin data. No or very minor concerns about relevance

continued

TABLE 47 The GRADE-CERQual assessment of confidence in the qualitative thematic synthesis findings (*continued*)

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
3.3: Using powered mobility safely – risky and disobedient behaviour	Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] Durkin,[109] Gudgeon and Kirk,[99] Feldner[116] and Cerruti and Biondi[103]	Minor methodological limitations: • One study did not adequately consider researcher–participant relationship (a further four papers did not clearly report researcher–participant relationship) and one study did not conduct rigorous data analysis (one further paper did not clearly report data analysis methods) • Lack of clarity – one study did not clearly report recruitment methods and lacked clarity in reporting findings, and one study lacked clarity in ethics considerations	Minor concerns about coherence: some concerns about the fit between the data from the primary studies and the review findings	Moderate concerns about adequacy: seven studies, which, together, offer thin data	No or very minor concerns about relevance: four studies included data relating to very young children; and all studies were from high-income settings	Moderate confidence	Seven studies with minor methodological limitations. Minors concerns about coherence. Moderate concerns about adequacy. No or very minor concerns about relevance
4.1: Anticipated and experienced outcomes from powered mobility – independent movement and independence	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Cerruti and Biondi,[103] Jonasson[110] and Cronin[134]	Moderate to serious methodological limitations: • Seven studies did not adequately consider researcher–participant relationship (a further five papers did not clearly report researcher–participant relationship), one study did not conduct rigorous data analysis (three further papers did not clearly report data analysis methods) and one study did not clearly report study findings (one further study lacked clarity in reporting findings)	No or very minor concerns about coherence	No or very minor concerns about adequacy: 15 studies, which, together, offer rich data	No or very minor concerns about relevance: seven studies included data relating to very young children; and one study was from an upper middle-income country	High confidence	15 studies with moderate methodological limitations. No or very minor concerns about coherence, adequacy and relevance

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
		• Lack of clarity – five studies did not clearly report recruitment methods, one study did not clearly report data collection methods, two studies did not clearly report research design and three studies lacked clarity in ethics considerations					
4.2: Anticipated and experienced outcomes from powered mobility – developmental benefits	Pritchard-Wiart *et al.*,[58] Evans and Baines,[62] McGarry *et al.*,[69] Nilsson and Nyberg,[74] Durkin,[109] Sonday and Gretschel,[101] Nilsson *et al.*[117] and Jonasson[110]	Moderate to serious methodological limitations: • Four studies did not adequately consider researcher–participant relationship (three further studies did not clearly report researcher–participant relationship), one study did not sufficiently consider ethics issues (two further studies lacked clarity in ethics considerations) and one study did not clearly report study findings • Lack of clarity – three studies did not clearly report recruitment method, three studies did not clearly report data analysis methods, one study did not clearly report data collection method, one study did not clearly report research design, and one study lacked clarity in reporting findings	No or very minor concerns about coherence	No or very minor concerns about adequacy: eight studies, which, together, offer rich data	No or very minor concerns about relevance: four studies included data relating to very young children; and one study was from an upper middle-income country	High confidence	Eight studies with moderate methodological limitations. No or very minor concerns about coherence, adequacy and relevance

continued

TABLE 47 The GRADE-CERQual assessment of confidence in the qualitative thematic synthesis findings (*continued*)

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
4.3: Anticipated and experienced outcomes from powered mobility – parent outcomes	Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Cerruti and Biondi[103] and Jonasson[110]	Moderate to serious methodological limitations: • Four studies did not adequately consider researcher–participant relationship (a further two studies did not clearly report researcher–participant relationship), one study did not conduct rigorous data analysis (one further study did not clearly report data analysis methods) and one study did not clearly report study findings (one further study lacked clarity in reporting findings) • Lack of clarity – four studies did not clearly report recruitment methods, one study did not clearly report data collection method, two studies did not clearly report research design and three studies lacked clarity in ethics considerations	No or very minor concerns about coherence	No or very minor concerns about adequacy: 10 studies, which, together, offer rich data	No or very minor concerns about relevance: six studies included data relating to very young children; and one study was from an upper middle-income country	High confidence	Ten studies with moderate methodological limitations. No or very minor concerns about coherence, adequacy and relevance

Finding[a]	Studies contributing to findings	Methodological limitations	Coherence	Adequacy	Relevance	GRADE-CERQual assessment of confidence in the evidence	Explanation of GRADE-CERQUAL assessment
5.1: Overall benefit of powered mobility	Pritchard-Wiart *et al.*,[58] Evans *et al.*,[59] Feldner *et al.*,[60] Kenyon *et al.*,[61] Evans and Baines,[62] McGarry *et al.*,[69] Durkin,[109] Gudgeon and Kirk,[99] Pituch *et al.*,[100] Sonday and Gretschel,[101] Wiart *et al.*,[102] Currier *et al.*,[105] Feldner,[116] Cerruti and Biondi,[103] Jonasson[110] and Cronin[134]	Moderate to serious methodological limitations: • Seven studies did not adequately consider researcher–participant relationship (a further six papers did not clearly report researcher–participant relationship), one study did not conduct rigorous data analysis (three further papers did not clearly report data analysis methods) and one study did not clearly report study findings (one further study lacked clarity in reporting findings) • Lack of clarity – five studies did not clearly report recruitment methods, one study did not clearly report data collection methods, two studies did not clearly report research design and three studies lacked clarity in ethics considerations	No or very minor concerns about coherence	No or very minor concerns about adequacy: 16 studies, which, together, offer rich data	No or very minor concerns about relevance: seven studies included data relating to very young children; and one study was from an upper middle-income country	High confidence	Sixteen studies with moderate methodological limitations. No or very minor concerns about coherence, adequacy and relevance

a See *Table 37* for descriptions of findings.

Appendix 11 Example of the powered mobility provision process for an NHS Wheelchair Service

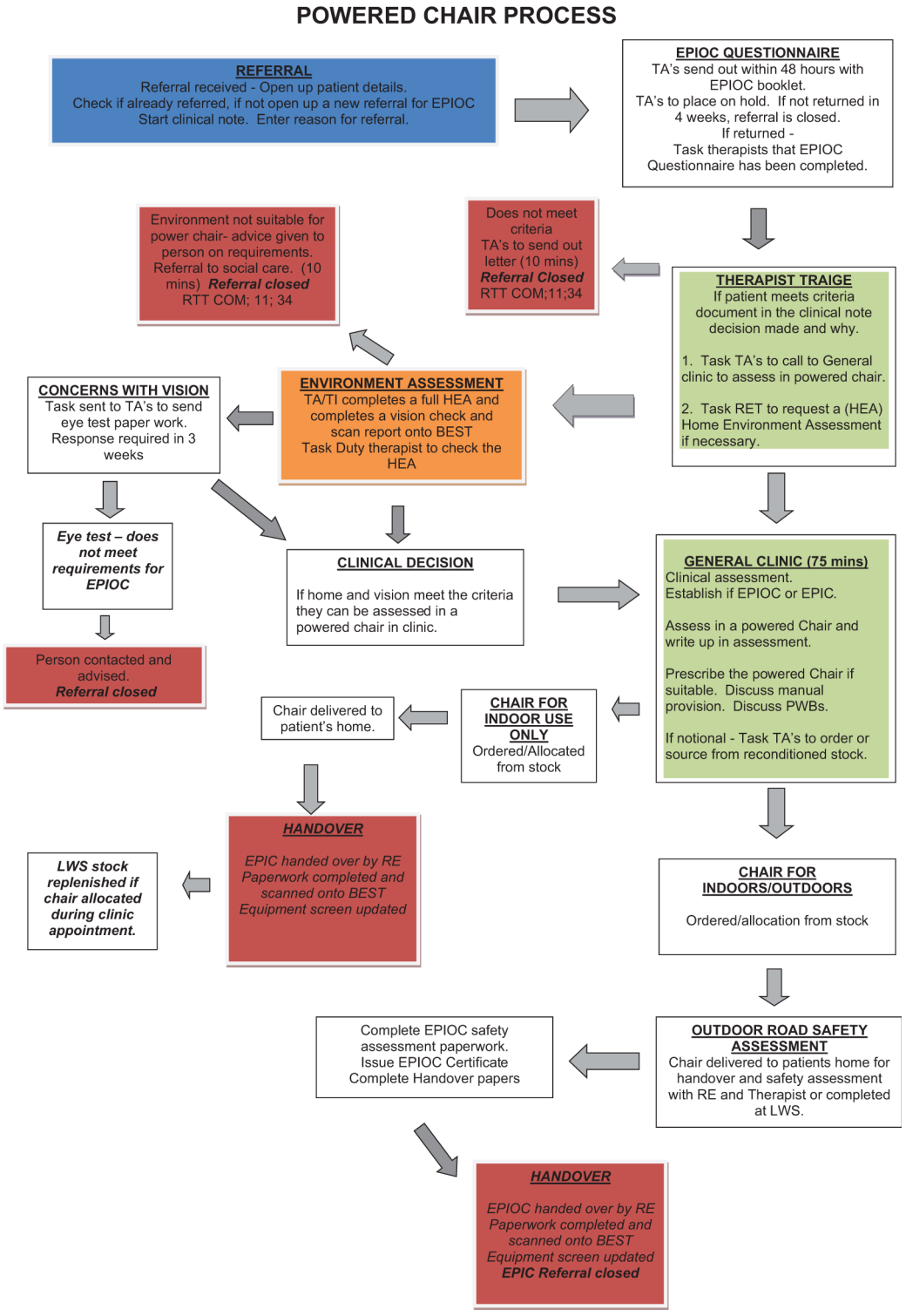

FIGURE 9 Example of the powered mobility provision process for an NHS Wheelchair Service. Reproduced with permission from Leeds Wheelchair Service, Leeds Teaching Hospitals NHS Trust, Leeds, UK.

Appendix 12 Tariff of costs associated with early powered mobility provision

TABLE 48 Early powered mobility equipment costs

Item	Source	Year	2018 cost (£)	Comment	Reference
Mean cost of powered wheelchair	Manufacturers/ suppliers	2019	3939	Costs of powered wheelchairs referred to by services, users, literature	Various, see *Powered wheelchair individual model costs* section of this table for specific models
Highest-cost powered wheelchair cited by NHS/ literature	Supplier (Better Mobility, Chesham, UK)	2019	8500	Koala Miniflex (Permobil AB) list price	www.bettermobility.co.uk/catalog/product.php?CI_ID=3080 (accessed 30 October 2019)
Lowest-cost powered wheelchair cited by NHS contacts	NHS Wheelchair Service manager	2018	1800	Lowest-cost powered wheelchair, referred to by NHS contacts and provided to very young children	Krys Jarvis, Shropshire Community Health NHS Trust, 2018, personal communication
Add-on cost for seating and accessories for powered wheelchair	Estimation from previous research	2016	Add 23%	Costs vary by individual need	Bray[151]
Mean cost of starter powered mobility device (designed for children aged < 5 years)	Manufacturers (MERU and Designability)	2019	4250	Maintenance included, cost derived from two models: Wizzybug (Designability) and Bugzi (MERU). Range £3500–5000	Personal communication: • Rae Baines, Designability, 2019 • Kate El-Bizanti, MERU Queen Elizabeth's Foundation for Disabled People, 2019
Cost of starter powered mobility device loan	Manufacturers (MERU and Designability)	2019	100–200	Item is loaned for refundable deposit of £100–200	• https://designability.org.uk/wp-content/uploads/2017/11/FRM-011-Wizzybug-Loan-Scheme-Information-Sheet-3.0-6th-November-2017.pdf (accessed 30 October 2019) • https://meru.org.uk/product/bugzi-loan-scheme-bugzi-deposit/ (accessed 30 October 2019)
Add-on cost for seating and accessories for starter powered mobility device	Estimation from previous research	2016	Add 6%	Costs vary by individual need	Bray[151]

continued

TABLE 48 Early powered mobility equipment costs (*continued*)

Item	Source	Year	2018 cost (£)	Comment	Reference
Estimated cost of adapted ride-on toy	GoBabyGo and retailers [Amazon (Amazon.com Inc., Bellevue, WA, USA) and fisher-Price]	2019	410	• GoBabyGo funding letter states US$500 ($300 for car and $200 for set-up) • Prices for unadapted toys around £120 in UK; US$239.99 = £196.76 (exchange rate $1 to £0.82, August 2019)	• James C (Cole) Galloway, University of Delaware, Newark, DE, USA, 2019, personal communication • www.amazon.co.uk/Disney-Cars-Lightning-McQueen-Quad/dp/B005GKB6XY/ref=sr_1_fkmr0_1?keywords=Pixar-Lightning-McQueen+ride+on+new%26qid=1572435117%26s=kids%26sr=1-1-fkmr0 (accessed 30 October 2019) • www.amazon.co.uk/Kiddieland-Lightning-McQueen-Activity-Limited/dp/B01GDO7YRI/ref=sr_1_6?keywords=Ride+on+toy+car+pixar%26qid=1572435337%26s=kids%26sr=1-6 (accessed 30 October 2019) • www.fisher-price.com/en-us/search-results?searchTerm=power+wheels+toys (accessed 30 October 2019)
Powered wheelchair individual model costs					
Invicta (RMS, Sittingbourne, UK)	NHS Wheelchair Service manager	2019	1800	Price may vary, depending on service	Krys Jarvis, personal communication
Zippie Salsa (Sunrise Medical, Brierley Hill, UK)	NHS Wheelchair Service manager	2019	2500	Price varied, depending on source	Personal communication: anonymous representative for AJM Healthcare (Hailsham, UK) and Derbyshire Wheelchair Service (Derby, UK), 2019
	Stakeholder representative		3100		Personal communication: anonymous patient representative from project advisory group, 2019
	Wheelchair supplier		4835		www.bettermobility.co.uk/catalog/product.php?CI_ID=2175 (accessed 30 October 2019)
Esprit Action 4NG Junior (Invacare Ltd)	Manufacturer (Invacare)	2019	1980	Price may vary, depending on service	Peter Hubbard, Invacare Ltd, 2019, personal communication
Koala Miniflex (Permobil AB)	Supplier (Better Mobility)	2019	8500	Price may vary, depending on supplier	www.bettermobility.co.uk/catalog/product.php?CI_ID=3080 (accessed 30 October 2019)
Sparky Paediatric (Pride Mobility Products Ltd, Bicester, UK)	Supplier (Complete Care Shop, Preston, UK)	2019	3150	Price may vary, depending on supplier	www.completecareshop.co.uk/wheelchairs/quantum-power-wheelchairs/sparky-paediatric-power-wheelchair-view-large?gclid=CjwKCAjwuqfoBRAEEiwAZErCsvGA4rm4SuxxUGtcEmtozUX_vyFRN6rJOWL99Ie9KT3LgW55Mzgg6xoCePgQAvD_BwE (accessed 30 October 2019)

TABLE 48 Early powered mobility equipment costs (*continued*)

Item	Source	Year	2018 cost (£)	Comment	Reference
Skippi (Ottobock, Egham, UK)	Supplier (Better Mobility)	2019	4455	Price may vary, depending on supplier	www.bettermobility.co.uk/catalog/product.php?CI_ID=2395 (accessed 30 October 2019)
Salsa 2 Mini (Sunrise Medical)	Supplier (Better Mobility)	2019	5565	Price may vary, depending on supplier	www.bettermobility.co.uk/catalog/product.php?CI_ID=2662 (accessed 30 October 2019)
K300 PS Junior (Permobil AB)	Supplier (Better Mobility)	2019	6881	Price may vary, depending on supplier	www.bettermobility.co.uk/catalog/product.php?CI_ID=3082 (accessed 30 October 2019)
Models not stated	NHS Disablement Service Centre manager	2019	2600	Cost represents the average cost of paediatric powered wheelchairs supplied by this centre. Includes equipment, overheads and engineering costs	Susan Hillman, Newcastle upon Tyne Hospitals NHS Foundation Trust, 2019, personal communication

TABLE 49 Adaptation costs associated with early powered mobility

Item	Source	Date	2018 costs (£)	Comment	Reference
Ramp to door	*Unit Costs of Health and Social Care 2018*[148]	2018	334	Materials (author annuitised 10 years at 3.5%)	Curtis and Burns, 2019[148]
Ramp to door	*Unit Costs of Health and Social Care 2018*[148]	2018	232	Staff costs NHS	Curtis and Burns, 2019[148]
Ramp to door	*Unit Costs of Health and Social Care 2018*[148]	2018	340	Staff costs HIA	Curtis and Burns, 2019[148]
Path to door	*Unit Costs of Health and Social Care 2018*[148]	2018	0	Materials (author annuitised 10 years at 3.5%)	Curtis and Burns, 2019[148]
Path to door	*Unit Costs of Health and Social Care 2018*[148]	2018	126	Staff costs NHS	Curtis and Burns, 2019[148]
Path to door	*Unit Costs of Health and Social Care 2018*[148]	2018	27	Staff costs HIA	Curtis and Burns, 2019[148]
Door widening	*Unit Costs of Health and Social Care 2018*[148]	2018	104	Materials (author annuitised 10 years at 3.5%)	Curtis and Burns, 2019[148]

continued

TABLE 49 Adaptation costs associated with early powered mobility (*continued*)

Item	Source	Date	2018 costs (£)	Comment	Reference
Door widening	*Unit Costs of Health and Social Care 2018*[148]	2018	290	Staff costs NHS	Curtis and Burns, 2019[148]
Door widening	*Unit Costs of Health and Social Care 2018*[148]	2018	241	Staff costs HIA	Curtis and Burns, 2019[148]
1 × ramp, path, widening (all costs)	N/A	2018	1726	Minimum cost of housing adaptation, based on data from *Unit Costs of Health and Social Care 2018*[148]	N/A
2 × ramp, path, widening (all costs)	N/A	2018	3452	Best estimate of cost of housing adaptation, based on data from *Unit Costs of Health and Social Care 2018*[148]	N/A
Average cost of Disabled Facilities Grant	Equality and Human Rights Commission[156]	2018	7500	No annuitisation, as we assume this includes staff cost	Equality and Human Rights Commission, 2018[156]
Mean Motability grant	Mot Living Ability	2018	2706	Calculated from Motability website, which states that in the previous year Motability provided £23M in charitable grants to 8500 customers[180]	Motability, 2019[157]

HIA, Home Improvement Agency; N/A, not applicable.

TABLE 50 Service support costs associated with early powered mobility

Item	Source	Year	2018 cost (£)	Comment	Reference
Assessment	NHS Improvement	2018	368	Unit cost reference: WC04	NHS Improvement, 2018[142]
Specialist modification without supply	NHS Improvement	2018	139	Unit cost reference: WC14	NHS Improvement, 2018[142]
Specialised complex wheelchair services	NHS Improvement	2018	429	Unit cost reference: WC13	NHS Improvement, 2018[142]
Repair and maintenance	NHS Improvement	2018	214	Unit cost reference: WC10	NHS Improvement, 2018[142]
Review	NHS Improvement	2018	232	Unit cost reference: WC11	NHS Improvement, 2018[142]
Review of substantial accessories	NHS Improvement	2018	143	Unit cost reference: WC12	NHS Improvement, 2018[142]
Training workshop	Go Kids Go!	2019	450	Average cost per child attending training workshop	Roy Wild and colleagues, Go Kids Go! 2019, personal communication

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